Fermilab
FY2003 Self-assessment
Process Assessment Report
For
Technical Division

04-Mar-2003

Division/Section performing assessment

Technical Division

Name of organization that owns assessed process

Technical Division

Organization Strategy

The Technical Division is participating in the construction of the Large Hadron Collider through the design and fabrication of Q2 Interaction Region quadrupoles (series designation LQXB). Through this project the Technical Division has been able to apply and improve upon its knowledge and infrastructure in superconducting magnet technology.

The Technical Division is also assembling the Q1/Q3 quadrupoles using KEK-fabricated cold masses, but this was outside the scope of this assessment.

Names of Personnel on Assessment team

Jamie Blowers, Quality Assurance Officer

Name of process assessed

US-LHC design, fabrication, measurement and shipment of Q2 (LQXB) magnets

Brief description of process to be assessed

Designing and fabricating superconducting magnets is a detailed and difficult task. The overall process includes design, procurement, fabrication, inspection, measurement and shipping.

Are metrics associated with this process? If so, what are they?

There are no metrics associate with this process.

What are the names of the procedures associated with this process?

The following documents were reviewed during the assessment:

US-LHC Quality Assurance Plan
US-LHC Project Management Plan
Report on the Production Readiness Review for the LQX Cryostat
LMQXB01 Test Plan
Various completed travelers, found in the archive or on the production floor
Weld Inspections on FNAL Q2a and Q2b Quadrupoles
Acceptance Plan for LQXB (LHC-LQX-ES-0008)

Are these procedures being followed? Are they current?

These procedures are being followed, and they are current.

Describe the methodology used to assess this process.

The methodology followed standard auditing practices. The Lead Auditor created a checklist (see attached) and sent it to the auditees prior to the audit. The audit consisted of interviews with those involved in radiation safety management. The interviews were based on the topics outlined in the checklist.

Results of the assessment:

The results of the assessment are **excellent**. This is a large and detailed project, and based on the sample assessed all the work appears to be well thought out, well planned and implemented appropriately. There were no major findings, and the minor issues are listed below.

The auditor interviewed at least 12 people working on the project, and in every case they knew exactly what their role was and how to do their work. The communication between tasks appears to be very good, and so work appears to be proceeding very well.

The customer for this project, CERN, has created a rather detailed Quality Assurance Plan for the construction of the LHC. As a supplier to CERN, the Technical Division is responsible for understanding the CERN-defined QA requirements, and incorporating them into our quality planning. This was done through linking the TD QA plan directly with the applicable sections of the CERN QA plan, and appears to be done well and complete. There is a small issue over the use of Quality Assurance Categories, and this is listed in the improvement items below. Technical Division should also continue to get the approval of the last CERN-required specifications. It is understood that this work is under way, and is dependant on the response from CERN.

Further details on the results of the assessment are in the attached checklist.

Identified opportunities for improvement

The following items were identified as opportunities for improvement:

1. Approve the Acceptance Plan and LQXB Interface Specification (already known).
2. Work towards incorporating all details of the test plan into one document.
3. Complete the IB1 checklist as soon as possible (already known).
4. Review the drawings to ensure that the ‘Quality Assurance Category’ (QAC) is identified appropriately.
5. Standardize the handling of parts kits and additional parts requests.
6. Complete the necessary Engineering Specifications and Operating Procedures for fabrication (already known).
7. Review the traveler/operating procedure training requirements (as defined in the travelers), and either do the training or change the requirements.
8. Revaluate the need for a traveler for the feed-through bus fabrication process.

Schedule for implementation of improvements

LQXB Interface Specification (LHC-LQX-ES-0010) was changed to status ‘Approval Closed’ on 10-April-2003 by the LHC Baseline Administrator.

Traveler for insulated bus assembly created and issued 15-April-2003 (TR-333721)

All others TBD.

Status of improvements from previous assessment

Issues found during prior reviews have either been closed or are in the process of being worked on and closed out.

Attachments (supporting data, worksheets, reports, etc.)

The following attachments have been incorporated into this report:

Checklist – the checklist used to conduct the assessment

Schedule – the schedule of the assessment

QA Plan – the US-LHC Fermilab Quality Assurance Plan

Weld Inspections – CERN document describing the weld inspections on FNAL Q2a and Q2b quadrupoles

Acceptance Plan – the draft Acceptance Plan for LQXB (LHC-LQX-ES-0008 rev 0.1)

LMQXB01 Test Plan – the test plan used for testing LQXB01 in the Magnet Test Facility in Technical Division

MQXB01 Final Assy Traveler – the final assembly traveler used to fabricate cold mass MQXB01

Reference	*Criteria*	*Results* *Fully Sat*	*Minor Issue*	*Major Issue*	*Comments*
QA plan 1.2 4)	Ship the completed quadrupole assemblies to CERN: - How do you assure that the magnets arrive in good condition? - Packaging specifications? - Shipping specifications? - Other specifications?	☒	☐	☐	TD supplies the shipping container, and communicates requirements to the shipping company. Testing has been done to collect impact data when shipping the magnets.
QA plan 1.3 [3], 4.3.3, and 8.3	MTF operations: - How are the MTF operations defined and documented? - How are the measurement results communicated to CERN? - Review run plan for LQXB01; - What is the status of the acceptance plan? - Have the action items from the PRR been closed out? - Equipment calibration/maintenance?	☐	☒	☐	The MTF operations are defined in the magnet run plans. Currently there are two documents, one for mechanical/quench testing, and another for alignment. *It may be worthwhile to combine these into one comprehensive run plan.* Records of the work are recorded in various logbooks, and a summary test report is written. The test report is reviewed and approved by a review board. Measurement results are provided to CERN in an MS-Excel format, and are loaded into EDMS. The Acceptance Plan is in draft form, and is being circulated for review. Actions from the PRR have either been closed out or are in process. Equipment maintenance was assessed during FY02 (audit number TD-2002-04). Calibration is done either by checking against a known standard, or by comparing one gage against another gage.
MQXP001 Discrepancy Report (MTF)	Were these issues taken care of for the first production magnet (LQXB01)?	☒	☐	☐	The issues described in this DR have been remedied.
QA plan 1.3 [1], 3.3.2, 4.3.3, 5.3, 5.4, 5.5, 8.2	Magnet fabrication: - Travelers, how are they managed (i.e. created issued, revised)?	☐	☒	☐	Travelers are used for all but one fabrication process. *It is recommended that a traveler be created for the bus assembly process.*

Reference	*Criteria*	*Results* *Fully Sat*	*Minor Issue*	*Major Issue*	*Comments*
	- Training; - Traceability, kits; - Inspection & testing; - Test status; - Equipment calibration/maintenance; - Discrepancies; - Records; - Have the action items from the PRR been closed out?				Travelers are created and controlled in the Process Engineering Group within the Engineering & Fabrication Department. The systems used are well under control. Training described in the traveler section 1.5 is not currently being documented. *This training should be completed and documented, or the requirement should be changed.*
Weld Inspections (version 9)	- Are all tests listed in table 3 incorporated into the fabrication process? - Verify that all welders for LQXB01 are appropriately qualified.	☒	☐	☐	All tests are incorporated into one of the assembly travelers. Weld samples from both coldmasses were tested by an outside firm, and confirmed to be acceptable.
QA plan 1.3 [2]	Parts control: - How is inventory managed? - How are parts issued to production? - Process Engineering work; - Material Control work;	☒	☐	☐	Inventory is managed with the TDINV database. This includes all the expected aspects of inventory control. Parts are issued either through a Parts Kit request or an Additional Parts Request. The paperwork is processed through ProEng, to the Acquisitioner, and then to IB4 for parts picking and delivery. The paperwork, which includes traceability information, is then included in the traveler.
QA plan 3.3.1, 8.2	Receiving inspection: - How is this work defined? - Traceability; - Training; - Equipment calibration/maintenance; - Review a sample of records.	☒	☐	☐	The details of what to do for receiving inspection are worked out between the inspection group and the appropriate engineer. These details are most often not documented, unless a drawing is marked up to define the specifics. Traceability is accomplished through the Routing Form.

Reference	*Criteria*	*Results* *Fully Sat*	 *Minor Issue*	 *Major Issue*	*Comments*
					Each inspector has years of experience using their tools, and they receive additional training on new equipment/software as needed. The QC lab uses a third-party calibration database (GageTrack) to manage calibration. The sample of equipment reviewed showed the system to be effective.
QA plan 7.0	Procurement: - How do you know what to buy? - Review a sample of records; - How is supplier oversight managed?	☒	☐	☐	Procurements are initiated by en Engineering Release (ER), Engineering Change Order (ECO), a Purchase Release, or a ProCard request. A review of their records Material Control is very diligent about having the appropriate records/approvals for all purchases. Supplier oversight is managed by requesting regular updates on work progress, and by conducting site visits as deemed necessary. In addition, the ProCard and MMS databases include notifications when parts have arrived, as well as when an order goes past a delivery date. Material Control has an excellent history of working with our suppliers to help ensure that contracts are successfully completed in a timely fashion.
QA plan 4.3.2, 6.0	Design: - How do you know that what we are making meets the customer requirements? - How are the customer requirements defined? - How was the design validated against the requirements? - How are design changes handled? - How are drawings/specifications	☒	☐	☐	The Production Readiness Review ensured that the design meets the customer requirements, since the customer participated in the review. Customer requirements are defined in technical specifications, which define the overall performance requirements of the devices. The design was validated against the requirements through the High Gradient Quadrupole prototyping program. This involved making short models of the magnets, and testing them in MTF.

Reference	*Criteria*	*Results* *Fully Sat*	*Minor Issue*	*Major Issue*	*Comments*
	managed? - What has been sent to CERN (EDMS)? - Is the QAC on the appropriate drawings? - What has been done regarding product reliability?				Design changes are handled through the ECO system. As needed, the customer is involved in the approval of substantial changes (the US-LHC project office makes this determination). TD drawings and specification are managed in the XDCS system (note: some specifications are also managed in the OnBase system). CERN has, or will, receive HPGL version of all the drawings (via CD), as well as all production records (via CD). The QAC is not on any drawings that we send, but the US-LHC Project Engineer confirmed that the title box added by CERN does include the QAC. Reliability: cycle testing on bellows and skin welds, along with a history of fabricating successful and reliable magnets.
		☐	☐	☐	

Questions:

1. How does TD know what its requirements are (e.g. WBS, MoU, SoW)?
2. How do we know that the magnets are meeting the design requirements (e.g. can we connect requirements in the magnet design to production/testing)?
3. What is your role?
4. How does your role fit into the entire production process?
5. In your own words, can you describe the purpose of the work you are doing?
6. Can you show me what you do?
7. How do you know that the outcome of your work is sufficient?
8. What do you do if you have a problem?
9. How does your work affect other people involved with the project?
10. What could be done to make things better?

TD-2003-04 LHC

Assessment Schedule

Task	Duration	Date	Time
Interviews – fabrication (IB3): • Rodger Bossert	90 min.	March 4	2:00pm
Interviews – D&T (ICB): • Mike Lamm	45 min.	March 5	10:00am
Interviews – D&T (IB1): • Mike Tartaglia	90 min.	March 5	11:00am
Interviews – D&T (ICB): • Phil Schlabach	150 min.	March 5	12:30pm
Interviews – D&T (ICB): • Sandor Feher	30 min.	March 6	8:00am
Interviews – design/shipping (ICB): • Jim Kerby	1 hour	March 6	10:00am
Interviews – parts control (IB4): • Doug Kelley, Les Peters	60 min.	March 6	11:30am
Interviews – inspection (IB4): • Ted Beale, Les Peters	45 min.	March 6	1:00pm
Interviews – procurement (ICB): • Marsha Schmidt	45 min.	March 6	1:45pm
Interviews – fabrication (ICB): • Jim Rife	90 min.	March 7	8:15am
Closing meeting (ICB cafeteria): • Meet with everyone to orally present assessment results.	20 min.	March 7	10:00am

Fermi National Accelerator Laboratory

United States Large Hadron Collider Accelerator Project

FERMILAB LHC ACCELERATOR PROJECT QUALITY ASSURANCE PLAN
Version 1

Approved, Technical Division Quality Assurance Officer — Date: 21-Nov-2001

Approved, US-LHC Fermilab Project Manager — Date: 21-Nov-2001

Approved, US-LHC Project Manager — Date: 21 Nov 01

Approved, Technical Division Head — Date: 21 Nov 01

Purpose

The purpose of this Quality Assurance Plan is to describe how quality assurance is planned and implemented for Fermilab's effort on the US-LHC Accelerator Project.

Each section of this document begins with a policy statement for the Technical Division. Fermilab's portion of the US-LHC Project adheres to the TD policies, unless otherwise stated.

Scope

The description and requirements in this plan are applicable to all activities included in Fermilab's portion of the US-LHC Accelerator Project (hereafter referred to as 'the Project').

Reference Documents

1. US-LHC Project Management Plan, available from http://tdserver1.fnal.gov/project/Us-lhc_official_docs/Governing_docs/PMP/
2. US-LHC Technical Design Handbook, available from http://tdserver1.fnal.gov/project/Us-lhc_official_docs/Controlled_docs/Technical/
3. Technical Division Quality Management Program TD-2010, available from http://www-td.fnal.gov/ (under "Tech Division Info")
4. Technical Division Self-Assessment Program TD-2020, available from http://www-td.fnal.gov/ (under "Tech Division Info")
5. Fermilab Procurement Manual, available from http://www-bss.fnal.gov/Procurement/
6. Fermilab Environmental, Safety & Health Manual, available from http://www-esh.fnal.gov/home/esh_home_page.page?this_page=800
7. Measurement & Test Facility magnet Run Plans, available from http://wwwtsmtf.fnal.gov/~tartagli/LHC/LHC.html

CERN documents (available from http://www.cern.ch/CERN/Divisions/EST/LHCQAP/qaphome.htm)

8.	Quality Assurance Policy and Project Organization	LHC-PM-QA-100.00
9.	Quality Assurance Contents and Status	LHC-PM-QA-101.00
10.	Quality Assurance Categories	LHC-PM-QA-201.00
11.	Glossary, Acronyms, Abbreviations	LHC-PM-QA-203.00
12.	LHC Engineering Vocabulary	LHC-PM-QA-205.00
13.	LHC Part Identification	LHC-PM-QA-206.00
14.	Drawing and 3D Model Management and Control	LHC-PM-QA-305.00
15.	Drawing Process - External Drawing	LHC-PM-QA-306.00
16.	Design Process and Control	LHC-PM-QA-307.00
17.	Manufacturing and Inspection of Equipment	LHC-PM-QA-309.00
18.	Handling of Nonconforming Equipment	LHC-PM-QA-310.00

CERN documents (available from http://rvuiller.home.cern.ch/rvuiller/Tisus/coordination.htm)

19.	MOU on Accelerator Mechanical Safety	TIS-TE-MB-98-74
20.	Weld Inspections on FNAL Q2a and Q2b Quadrupoles	

CERN document (available from at http://lhc.web.cern.ch/lhc/, under "LHC Design")

21. LHC Parameters and Layouts Database

1.0 Program

1.1 *Policy*

The policy of the Technical Division is to develop, document, and maintain its quality management program, so that the division may satisfy the needs of its customers.

1.2 *Mission*

The mission of *Fermi National Accelerator Laboratory* is:

"Advancing the understanding of the fundamental nature of matter and energy by providing leadership and resources for qualified researchers to conduct basic research at the frontiers of high energy physics and related disciplines."

The mission of the *Technical Division* is:

"The development, design, fabrication or procurement, and testing of accelerator and detector components."

The mission of the *US-LHC Accelerator Project* at Fermilab is to:

1) Design, build, and test interaction region quadrupole cold masses;
2) Design, build, and test interaction region quadrupole cryostats;
3) Assemble Fermilab and KEK-built quadrupole cold masses into Fermilab-built cryostats;
4) Ship the completed quadrupole assemblies to CERN.

1.3 *Objectives, Goals and Functional Responsibilities*

[1] <u>To design and fabricate cold masses and cryostats</u>.

The Engineering & Fabrication Department is responsible for the design of the manufacturing tooling and the cold masses and cryostats that are required in the Project.

[2] <u>To procure, inspect, inventory, and deliver the various materials needed for this project</u>.

The Material Control Department is responsible for these functions. The Engineering & Fabrication Department interfaces with the Material Control Department and other groups, as required, to assist the procurement section of Fermilab in procuring the needed material.

Inspection of the procured materials will be required. See section 8.0 for details. The storage and inventory of the components for the assemblies may be required in some cases.

[3] To test the completed assemblies.

The Development & Test Department is responsible for the design and fabrication of the test equipment, and for testing the completed assemblies. See section 8.0 for specifics on Inspection and Acceptance Testing.

[4] To oversee the scheduling of milestones, to budget and control cost, and to report to the US-LHC Project Manager timely status reports, as required by the project office.

These functions are assigned to the Fermilab Project Manager, who is assisted by his staff and other project personnel. This includes reporting on the resource requirements and status of the project to the Technical Division Head.

[5] To create and maintain a Quality Assurance Plan.

Although quality is the responsibility of every Fermilab employee, the task of creating and maintaining the QA Plan is assigned to the Quality Assurance Officer.

[6] To perform the required material development for this project.

This task is assigned to the Material Development Laboratory in the Engineering & Fabrication Department, on an as-needed basis.

[7] To provide a qualified staff for the performance of this project and to provide the needed laboratory work space.

This function is the responsibility of the Technical Division Head, acting on input supplied by the Fermilab Project Manager.

1.4 *Organizational Structure*

The organization chart for the Project is defined in Appendix 4 of the US-LHC Project Management Plan (PMP). A more detailed chart is located in Appendix I.

Clear and frequent communication is always encouraged among the project participants, and is critical to the success of the Project. Informal communication via notes, phone calls, electronic mail, and informal discussions are exchanged frequently between the participants. This information flow encourages the exploration of the viability of plans and solutions, and allows for the resolution of any issues that arise. Although it is not a project requirement, the distribution of copies of informal correspondence to all participants is desirable to keep everyone apprised of the most current information available. More information regarding project communications is defined in section 3.4 of the US-LHC PMP.

1.5 *Roles, Responsibilities and Authority*

1.5.1 Fermilab Project Manager

- Fermilab Project Manager reports to the US-LHC Project Manager;
- Is responsible for delivering acceptable completed quadrupole assemblies to CERN;
- Implements the QA Plan;
- Assures the quality of the delivered products;

More details regarding the responsibilities for the Fermilab Project Manager are defined in section 3.3.5 of the US-LHC Project Management Plan (PMP).

1.5.2 Level 3 Managers

- Level 3 managers are responsible for the day-to-day coordination and progress of the WBS Level 3 task to which they are assigned.

More details regarding the responsibilities for the Level 3 managers are defined in section 3.3.7 of the US-LHC PMP.

1.5.3 Quality Assurance Officer

- Responsible for the creation and maintenance of the QA Plan;
- Responsible for aligning the requirements of the CERN LHC QA Plan with the practices of the Project, and identifying differences as appropriate.
- Responsible for providing support to the US-LHC project staff throughout the project.

1.5.4 Technical Division Head

- Provide support to project personnel, and aid in solving problems that cannot be solved on a lower level.

1.6 *Organizational Interface*

1.6.1 Fermilab LHC Project Office/US-LHC Project Office

- As stated above, the Fermilab LHC Project Manager reports to the US-LHC Project Manager. The Fermilab LHC Project Manager is responsible for following the guidelines set up by the US-LHC Project Office, and for reporting on the status of the Project;
- All Project documents that are to be approved by CERN, e.g. specifications, are routed through the US-LHC Project Office.

1.6.2 Fermilab LHC Project Office/TD-HQ

- Communicate project status on a regular basis and when changes occur;
- Determine staffing requirements for the Project within TD;
- Resolve resource allocation issues, e.g. draftsman assignments, machine shop priorities, and space allocation.

1.6.3 Technical Division Procurement/Fermilab Business Office

- TD Procurement representative attends weekly Project design/procurement meetings with the Fermilab Business office;
- Project management attends these meetings as needed.

1.6.4 Fermilab LHC Project Office/Level 3 Managers

- Develop requirements and specifications to fulfill the goals of the Project. The Fermilab Project Manager will approve requirements and specifications.

1.6.5 Fermilab LHC Project Office/CERN

- As CERN is the customer of the US-LHC project, regular communication is necessary for a successful completion of the Project. Conversations (via telephone, e-mail, video conference, travel, et cetera) frequently take place between the Fermilab Project Manager, Fermilab Project Engineers and CERN LHC representatives. As the Project advances, these conversations are recorded in drawings and specifications, and are approved by appropriate personnel;
- In addition, CERN supplies several parts used in the inner triplet final assembly. Communication between the Project and CERN also include defining and documenting the requirements related to these parts.

1.6.6 Fermilab LHC Project Office/KEK

- KEK is responsible for the design and manufacture Q1/Q3 cold masses. Fermilab is responsible for final assembly of KEK cold masses into the cryostats. This means that conversations (via telephone, e-mail, video conference, travel, et cetera) frequently take place between the Fermilab Project Manager, Fermilab Project Engineers and KEK LHC representatives. As the Project advances, these conversations are codified, and approved by appropriate personnel, in drawings and specifications.

1.7 *CERN LHC QA Plan*

The CERN QA Plan has been read and understood by the QA Officer. Links between current Project practices and CERN QA documents have been incorporated into this document. The Technical Division QA program, as defined in this document and implemented for the production of LHC devices, meets all requirements defined in the CERN QA Plan.

2.0 Personnel Training and Qualifications

2.1 *Policy*

The policy of the Technical Division is to hire and maintain personnel who posses the appropriate level of skill, experience, and academic qualifications to support the achievement of the Project.

2.2 *Training*

All Project personnel (including contract personnel) have the appropriate experience and/or are provided training to ensure that they are capable of performing their assigned work to the appropriate level of safety, efficiency and quality.

Training may come from several sources such as mentoring provided by physicists, engineers, supervisors, lead personnel, consulting firms, technical operating manuals, and other sources. Job-related training records of all assigned personnel, for work related to the Project, are maintained by the respective supporting organization.

2.3 *Qualifications*

Qualifications for personnel working on the Project are based upon the responsibilities of the position and project needs, which define the level of education, extent of work experience, knowledge and specific skill requirements.

3.0 Quality Improvement

3.1 *Policy*

The policy of the Technical Division is to continually improve in all areas and activities for which it is responsible.

3.2 *Quality Responsibilities*

All personnel performing a function at Fermilab are responsible for quality and are encouraged to promptly report conditions adverse to quality such as deviations, deficiencies, failures, defective items or processes, and nonconformances, to the appropriate level of management.

Personnel closest to the daily operation or activity are in the best position to understand and report nonconforming conditions, and are encouraged to participate in quality improvements to meet the needs of the customer and to achieve the objectives of the project mission.

Management is responsible for providing the necessary resources for conducting root cause analysis and for implementing corrective and preventive actions.

3.3 *Performance Analysis*

The "Quality Control Report" and "Discrepancy Report" processes, described below, meet the requirements of CERN QA document LHC-PM-QA-310.00 "Handling of Nonconforming Equipment".

3.3.1 Supplier Performance

Supplier performance problems are identified and reported through the mechanism of Quality Control Reports (QCRs), generated by the Material Control Department's Incoming Inspection group for items such as incoming parts, assemblies, and hardware. These reports are reviewed and approved by the responsible authority/physicist (or designee) of the area or activity in which they will be used and by the Material Control Department Head (or designee). The review covers problems that may have significant programmatic effect or risk factors affecting cost, schedule, ES&H (personnel safety), or configuration. The appropriate disposition is given, i.e. scrap, return to vendor for replacement, rework at vendor, rework in house, or use as is. These reports are reviewed for supplier performance problems or trends and are used as a basis for cause analysis and necessary corrective action.

3.3.2 Work Process Performance

Discrepancy Reports (DR) are used to document problems during assembly or fabrication such as deviations, deficiencies, failures, defective items/materials or processes, malfunctions, trends, and/or non-conforming conditions.

The responsible authority of the activity or area of occurrence reviews these discrepancy reports for technical evaluation, cause determination, disposition, and corrective/preventive action recommendation. If rework is required, instructions are recorded on the DR form. After rework is completed the item is retested against the specification and is dispositioned accordingly.

Process Engineering performs a review of these reports to ensure that reports are completed properly and that preventive action is adequate; the QA Manager may also recommend follow up corrective/preventive action or verification/validation as required. These discrepancy reports are used as a basis for trends, cause analysis, and/or lessons learned.

4.0 Documents and Records

4.1 *Policy*

The policy of the Technical Division is to maintain adequate documentation and records to ensure quality requirements are met, while recognizing the objective of minimizing paperwork and overhead cost.

Detailed documentation of all Project components, from design, continuing through all fabrication and testing processes, until final performance measurement, are essential, as Fermilab personnel will not be involved in the operation and maintenance of the LHC.

4.2 *Responsibilities*

- Quality Assurance is responsible for the release, revision and distribution of the Project QA Plan.
- The Engineering & Fabrication Department is responsible for the control of documents and data pertaining to engineering specifications, engineering procedures, cold mass and cryostat drawings and travelers.
- The Development & Test Department is responsible for the control of documents and data regarding completed assembly performance testing.
- The Material Control Department is responsible for the control of documents and data associated with the procurement of materials for the Project.

4.3 *Procedures*

4.3.1 Controlled Documents

Controlled documents are created, implemented, and maintained at a level commensurate with the level of work being performed and as dictated by sound quality assurance practices.

The Project maintains the following documents under document control:

- US-LHC Fermilab Quality Assurance Plan
- Engineering drawings and specifications
- Travelers

All controlled documents:

1. Are reviewed and approved by authorized personnel prior to being issued/revised.
2. Have a revision history maintained.
3. Are available to all personnel who need access.

4.3.2 Drawing and 3D Model Management

- Fermilab utilizes its internal drawing management system to create, approve, release and manage Project drawings.
- Fermilab will deliver HPGL plot files of 2-D drawings to CERN.
- All specifications, and their associated drawings, are sent to CERN prior to starting full production. The remainder of the drawings are provided after production has started, but before the first device is shipped to CERN.
- "As-built" drawings will be sent with the device. Device labels include the appropriate version of the assembly drawing.
- The Project's practices for managing drawings and 3D models meet the intent of CERN QA documents LHC-PM-QA-305.00 "Drawing and 3D Model Management and Control" and LHC-PM-QA-306.00 "Drawing Process - External Drawing".

4.3.3 Quality Records

Along with the records defined in section IV of the Safety MoU, the Project provides CERN the following records for each delivered device:

- A set of completed travelers - hard copies sent with the completed assembly and scanned copies provided to CERN;
- All Discrepancy Reports issued during the assembly process - hard copies sent with the completed assembly and scanned copies provided to CERN;
- Results of the performance measurements - a hard copy summary is sent with the completed assembly and electronic files provided to CERN.

Scanned images are provided to CERN in Adobe® Portable Document Format (PDF)[1].

The procedures and practices used by the Project to manage records meet the requirements defined in section 12 of CERN QA document LHC-PM-QA-309.00 "Manufacturing and Inspection of Equipment".

[1] Adobe PDF is a trademark of Adobe Systems Incorporated in the United States and/or other countries.

5.0 Work Processes

5.1 *Policy*

The policy of the Technical Division is that work processes be well thought out, appropriately documented and reviewed, and that they be carried out by competent and effective workers.

5.2 *Responsibilities*

- The Fermilab Project Manager's responsibility, as defined in 1.5.1, includes administering, planning, organizing, and controlling the Project to meet the technical, cost, and schedule objectives.
- The individual Project worker is the first line in ensuring quality. They are responsible for following the procedures defining the assembly and quality control checks in the fabrication of the assemblies, i.e. travelers. They also have the authority to report any possible nonconformities to management, and may participate in cause analysis and continuous improvement.
- The department heads are responsible for ensuring that people who are assigned to tasks have the appropriate academic qualifications, professional certifications, or skills and experience to carry out the work successfully (see section 2).
- The Fermilab Project Manager and the Project engineers are responsible for planning, authorizing, and specifying (to an appropriate level of detail), the conditions under which work is to be performed. This includes the calibration of measuring and test equipment (see section 8). This group also specifies which work is sufficiently complex or involves sufficient hazard to be performed to written procedures.
- The Engineering & Fabrication Department is responsible for the inspection and test status, identification and traceability, and for the creation and maintenance of the travelers for the magnets (see section 5.4).
- The Material Control and Engineering & Fabrication Departments share responsibility for the handling, storage, and preservation of components and completed assemblies.

5.3 *Production Process Control*

Appendix II defines the workflow for the fabrication of the Q2 magnet assemblies, which are built entirely at Fermilab. It identifies each process step, the traveler number(s), the serialization method, and the quantities of each sub-assembly needed to build one complete assembly. For the Q1 and Q3 assemblies, whose cold masses are provided by KEK, only the last two steps are executed. These will have their own traveler document numbers and assembly serial number series.

The Engineering & Fabrication Department Head, in conjunction with the Fermilab Project Manager and Project engineers, is responsible for ensuring that production processes are carried out under controlled conditions. When planning the production processes, the following are considered:

- All applicable government safety and environmental regulations;
- Use of travelers (or other such work instructions) to document the methods of production. These should be used when the absence of such procedures could be adverse to quality;
- Defining suitable equipment and work environment to ensure quality;
- Defining suitable maintenance of equipment to ensure continuing process capability;
- Defining the criteria for workmanship in the clearest practical manner. Examples of this are work instructions that document tolerances for process parameters, samples or pictures of "quality" product, samples or pictures of poor quality or failure modes to look for;
- Level of education and experience required for production personnel;
- Training needs for production personnel.

The procedures used to control production meet the requirements defined in section 5.3 of CERN QA document LHC-PM-QA-309.00 "Manufacturing and Inspection of Equipment".

5.4 *Travelers*

A system of travelers is used to define the sequence of fabrication, inspection, and testing to be performed for the assemblies. Witness/Hold points are designated in travelers at a turning point or important juncture of the fabrication. Travelers provide for sign-off by qualified personnel and are dated at the completion of each fabrication sequence, welding operation, and inspection/test procedure by designated inspection/test personnel, fabrication personnel, or welding personnel to assure completion, date completed, and sequence of required operations.

Training of project personnel in the usage of travelers is accomplished with a "walk-through". The "walk-through" training is conducted and documented by Process Engineering. The initial training simulates an actual operation (e.g. coil winding) using the traveler in a step by step sequence. The goal of the initial training is to familiarize all personnel with the proper usage of travelers in general, as well as to help everyone understand how the particular operation is designed to be completed.

Subsequent training of traveler revisions may be accomplished by routing the revised traveler to the appropriate personnel for signature, signifying that the revised traveler has been read and understood.

5.5 *Identification, Traceability and Test Status*

All finished components are identifiable with names and serial numbers that are located on the unit and its accompanying traveler(s). Serial numbers are marked on the unit according to the *Cryostat Final Assembly Traveler* (333644), which meets the requirements in CERN QA document LHC-PM-QA-206.00 "LHC Part identification" and section 7 of LHC-PM-QA-309.00 "Manufacturing and Inspection of Equipment".

Sub-assemblies are identified appropriately. The method of identification depends on the sub-assembly and the scope of the label. Some possible identification methods include:

- A stamp or label containing pertinent information is placed on the device;
- A tag containing pertinent information is affixed to the device;
- Serial numbers may be assigned if the device is sufficiently complex (the use of a traveler to fabricate a sub-assembly usually means that the sub-assembly is assigned a serial number);
- Sometimes a sub-assembly will have no physical label, in which case we rely on people, and the corresponding drawings, to identify the parts.

The lot/batch/serial numbers of the parts going into the unit are recorded on the traveler, and so it is the traveler that is the main document used for traceability.

While it is being fabricated, the test status of the unit is identifiable using the accompanying traveler, i.e. the traveler will show how far along the unit is in the assembly and test process, as well as the results of the QC checks. When the unit is completely assembled, it is tagged showing the test status. The methods used to identify test status meet the requirements defined in section 14 of CERN QA document LHC-PM-QA-309.00 "Manufacturing and Inspection of Equipment".

5.6 *Handling, Storage, Packaging and Delivery*

The Material Control and the Engineering & Fabrication Departments are both responsible for the proper handling of the components and completed magnet assemblies. Handling methods are defined with procedures and/or travelers, as appropriate.

The Material Control Department is responsible for the storage of most equipment, materials, completed assemblies, and related devices. The Material Control Department Head is responsible for establishing, documenting, communicating, and carrying out practices and procedures that ensure that items are stored and maintained to prevent damage, loss, or deterioration.

The Material Control and the Engineering & Fabrication Departments are both responsible for the proper packaging and delivery of the completed assemblies to CERN. Proper packaging methods are defined in packaging standards and/or drawings/specifications. Proper delivery methods are defined in the contract between Fermilab and the transporting organization.

The methods used to handle, store, package and delivery assemblies to CERN meet the requirements defined in section 15 of CERN QA document LHC-PM-QA-309.00 "Manufacturing and Inspection of Equipment".

5.7 *CERN Supplied Products*

CERN is responsible for providing the following components to the Project:

- MQXA (Q1 and Q3) cold masses (manufactured by KEK);
- MCBX, MCBXA and MQSXA corrector magnet assemblies;
- Quench protection heaters;
- Temperature sensors;
- Warm-up heaters (120 W);
- Beam tubes;
- Vacuum vessel bellows.

CERN is responsible for the quality of the components listed above. The Project is responsible for verification, storage and maintenance of the components after they have been received at Fermilab. Incoming inspection, proper handling and proper storage will ensure the quality of the CERN supplied components after they have been received.

Damaged components go through the QCR or DR process (see section 3.3), and are reported to CERN through appropriate channels. Lost components are also documented and reported to CERN through appropriate channels. The procedures used to handle material supplied by CERN meet the requirements defined in section 9 of CERN QA document LHC-PM-QA-309.00 "Manufacturing and Inspection of Equipment".

6.0 Design

6.1 *Policy*

The policy of the Technical Division is to ensure that designs perform as intended while minimizing cost. This is accomplished by having competent people incorporate sound engineering and scientific principles and appropriate technical standards into designs.

The design process used by the Project meets the requirements of CERN QA document LHC-PM-QA-307.00 "Design Process and Control".

6.2 *Design Input*

General design inputs are recorded in the CERN web-based "LHC Parameters and Layouts database". Design requirements specific to the US-LHC project were initially recorded in the Technical Design Handbook (TDH), and currently are defined in "Functional Specifications" (refer to section 5.4.1 of LHC-PM-QA-307.00 "Design Process and Control").

"Interface Specifications", for components interfacing with Fermilab-built magnets, are also used as inputs into the design process (refer to section 5.4.1 of LHC-PM-QA-307.00 "Design Process and Control")

6.3 *Design Output*

Interface Specifications, specific to Fermilab-built magnets, are design outputs. The purpose of interface specifications is to ensure that all groups are aware of the magnet assembly interfaces, and so that these groups are given the opportunity to review and provide feedback on these interfaces.

Drawings, material specifications and procurement specifications are outputs of the design process, and constitute the baseline design configuration. "Quality Assurance Categories" (QAC) are also an output of the design process and are recorded on the drawings, in accordance with CERN QA documents LHC-PM-QA-201.00 "Quality Assurance Categories" and LHC-PM-QA-306.00 "Drawing Process External Drawings". QACs are applied at the magnet level, and not at the component or part level, and have been defined to be category "B" for the magnet assembly.

The Project engineers are responsible for the creation and maintenance of the drawings and specifications for their portion of the Project.

All drawings and specifications are maintained as controlled documents (see section 4.4.1 of this document).

6.4 *Design Reviews*

At the conclusion of each phase of the Project, a documented, systematic, internal review is conducted to ensure that the final design and supporting data will meet design code requirements and standards. The reviews identify and anticipate problem areas, inadequacies, initiate corrective action, and includes representatives of all functions affecting quality as appropriate to the phase being reviewed. These formal reviews are used as a basis of assessing design reliability, ES&H, safety issues, quality problems, design improvement, and design practicality.

Results from the reviews are used as a basis for verifying that design outputs meet the design input requirements. More details regarding design reviews can be found in section 4.2.3 of the US-LHC Project Management Plan (PMP).

6.5 *Design Validation*

Designs are validated through the testing of the complete prototype system (or subsystem) during and after assembly, against the performance specifications. This testing includes the utilization of the Technical Division Magnet Test Facility (MTF).

6.6 *Design Changes*

Appropriate design controls are incorporated into the Project by using configuration management. Any changes to the magnet design, as defined in the drawings and specifications, must be reviewed and approved by the appropriate level of management (see section 5 of the US-LHC Project Management Plan, Change Management and Contingency Management - note that descriptions for change management in this section of the QA plan supercede the US-LHC Project Management Plan).

In practice, there are two types of change management processes. One for changes internal to the Project, and one for changes external to the Project.

Internal changes are changes that do not affect other systems outside of the scope of work for Fermilab. These changes are handled through the Technical Division ER/ECO procedure (5500-ES-360000). These changes do not need to be reviewed by the US-LHC Project Office, unless they affect configuration.

External changes are changes that have an impact on other systems outside the scope of work for Fermilab. An example is when a change affects how a CERN part will connect to the Fermilab-made magnet.

The overall change control process for external changes is as follows:

1. Proposed changes are recorded, in the form of updates to engineering specifications and drawings, and sent to the US-LHC Project Office.
2. The US-LHC Project Manager reviews the proposed changes, and:
    a) Sends them back to the Project for clarification;
    b) Approves the changes and places the document(s) into CERN EDMS for review by CERN; or
    c) Rejects the changes.
3. The proposed changes go through a review in CERN EDMS.
4. The proposed changes are approved and released in CERN EDMS, or are returned for revision or clarification.

7.0 Procurement

7.1 *Policy*

The Technical Division policy is to ensure that items and services provided by suppliers meet the requirements and expectations of the end-users at minimum cost.

7.2 *Requirements*

The Fermilab contract with the DOE specifies a variety of management controls to be applied to procurements and sub-contracts through the applicable DOE orders, DOE Acquisition Regulations (DEAR), and Federal Acquisition Regulations (FAR). To this end, all procurement activities are performed in accordance with the *Fermilab Procurement Policy and Procedures Manual* and the *Fermilab ES&H Manual*.

Only approved material is used in the production of the assemblies. The Material Control Department has the responsibility of procurement for the Project.

7.3 *Supplier Qualification and Selection*

Suppliers are evaluated and selected on the basis of their ability to meet subcontract requirements. These requirements are appropriately defined in approved engineering drawings and specifications, and include specific quality assurance requirements.

Topics that are usually evaluated include, but are not limited to:

- Quality assurance program
- Ability to meet all requirements
- Cost
- Financial resources
- Work history

7.4 *Budget Authority*

The Division Head, in conjunction with the budget defined by the US-LHC Project office, assigns expenditure level to individuals responsible for a specific work package. Procurement of items and services that are above the stated expenditure level require Division Head review and approval.

Expenditure levels are defined in the document *Technical Division Budget Codes & Signature Authority*, which is maintained on the fnts03 server.

7.5 *Make-Buy Decisions*

The fabrication of the magnet assemblies involves many "make or buy" decisions. The make-buy decision is based on a preference for providing hardware on a least-cost basis, giving due regard to such considerations as quality, capability and schedule. In general, bids are normally opened to outside suppliers. However, work will remain within Fermilab if it requires close engineering or scientific supervision, interaction between many trades or shops, involves materials or procedures not familiar to outside shops, or is dependent on capabilities unique to Fermilab.

8.0 Inspection and Acceptance Testing

8.1 *Policy*

The policy of the Technical Division is to ensure that all items, components, and services meet the specified requirements. This is verified through the use of inspection and acceptance testing.

8.2 *Requirements*

The Fermilab Project Manager and the Project engineers define the types of work that require formal inspections and acceptance testing. When an inspection or acceptance test is performed, the characteristics and processes to be inspected or tested, the inspection techniques to be used, the hold points, and the acceptance criteria are defined, as appropriate.

Inspection and acceptance testing (to include receiving, in-process, and final) are performed in accordance with proper training and/or written procedures.

The Material Control Department works with the Project personnel to define and document receiving acceptance testing for incoming materials. The traveler defines the testing during the assembly of the magnets (in-process). The agreement between the Project and CERN regarding weld inspections and qualification is defined in the document "Weld Inspections on FNAL Q2a and Q2b Quadrupoles".

The Magnet Test Facility (MTF) conducts the final performance testing of the completed assemblies. Cold tests of all the completed assemblies that are made from Fermilab-built cold masses will be performed, including quench training, field quality measurements and determination of the quadrupole axis. The first two completed assemblies made from KEK-built cold masses will be cold tested. The rest of the KEK-built quadrupoles will be tested at room-temperature for field axis measurements. The complete MTF test plans are defined in "run plan" documents.

All equipment which effects product quality (or is used to make a decision which effects product quality) is calibrated at prescribed intervals, and is appropriately identified with its calibration status. In general, calibration reference standards are traceable to NIST or other national/international organizations. If no national standard exists then the basis used for calibration is appropriately documented.

The procedures and practices used by the Project for inspections and calibrations meet the requirements of sections 8, 11 and 13 of the CERN QA document LHC-PM-QA-309.00 "Manufacturing and Inspection of Equipment".

8.3 *Records*

To allow for traceability, adequate records are maintained for all inspections and tests. These records include observations made, inspection/test results, identification of the personnel conducting the inspection/test, and date. Refer to section 4.3.3 for more details regarding records.

9.0 Quality Assessment

9.1 *Policy*

The policy of the Technical Division is to regularly assess the division's effectiveness in meeting it's objectives, goals, and compliance to orders and regulations. This is accomplished using the Technical Division Self-Assessment Program.

9.2 *Requirements*

Technical Division management will evaluate the division's role in the Project, in order to ensure that the Division continues to fulfill the requirements of the Project.

Management systems for performing and assessing adequacy of work on the Project, including activities that relate to planning, scheduling, and cost control are described in the following documents:

1. US-LHC Project Management Plan
2. Technical Division Quality Management Program
3. Technical Division Self-Assessment Program

9.3 *Methods*

Details from the TD Self-Assessment Program are not repeated here. Assessments are made using formal and informal meetings and other communications. Examples are:

- Division Head meeting with department heads or other supervisory staff
- Department heads meeting with line supervisors and other lead personnel
- Suggestions and recommendations from Project personnel
- Design Reviews & Production Readiness Reviews
- Independent assessments

9.4 *Feedback*

Information gathered during assessments is used to provide feedback to Project personnel. This information allows Project personnel to make improvements and any necessary corrective/preventive actions, so that the goals of the Project may be met.

Revision History

Version	Date	Section No.	Specifics
1	21-Nov-2001	All	First version

Controlled Distribution

Technical Division library	
Fermilab Project Manager	Jim Kerby
Technical Division Quality Assurance Officer	Jamie Blowers
US-LHC Project Office	Phil Pfund

Fermilab Project Manager
Jim Kerby

Quality Assurance Manager
Jamie Blowers

Interaction Region Quadrupoles 1.1.1
Jim Kerby

Interaction Region Layout and Integration 1.1.5
Tom Peterson, Mike Lamm

FNAL Accelerator Physics 1.4.1
Tanaji Sen

Interaction Region Quadrupole Tooling 1.1.1.1
Jim Kerby

Interaction Region Quadrupole Cold Mass 1.1.1.2
Rodger Bossert

Interaction Region Quadrupole Cryostat 1.1.1.3
Tom Nicol

Interaction Region Quadrupole Testing 1.1.1.4
Phil Schlabach

Interaction Region Quadrupole Shipping 1.1.1.6
Tom Nicol

Revisions:

24-Nov-2001	Original
24-April-2002	Added Jamie Blowers; and changed John Carson to Jim Kerby (Tooling 1.1.1.1)

Q2 Assembly Workflow

Inner/Outer Cable Insulation (quantity 8 each)
333480/333481
MQXBI-www/MQXBO-www

Inner/Outer Cable Preform (8 each)
333484/333485

Inner/Outer Wedge Insulation (8 each)
333482/333483

Inner/Outer Coil Winding (8 each)
333486/333487

Inner/Outer Coil Curing (8 each)
333488/333489

Inner/Outer Coil Inspection (8 each)
333490/333491

Inner/Outer Coil Insulation (8 each)
333581/333582

Coil Assembly (2)
333494
MQXBC-0yy

Collared Coil Keying (2)
333495

End Clamp Installation (2)
333496

Yoke and Skinning Assembly (2)
333497
MQXByy

Final Coldmass Assembly (2)
333498
MQXByy

Module Assembly (1)
333643
LMQXBzz

Cryostat Final Assembly (1)
333644
HCLQXB_001-FL0000zz
(Fermilab uses LQXBzz for all production documentation)

Interpretation of the assembly workflow:

Process description

Quantity of each component that goes into a complete magnet assembly

Inner/Outer Cable Insulation (quantity 8 each)
333480/333481
MQXBI-www/MQXBO-www

Document number of the traveler used for the process

Serialization system; the upper case letters indicate the series designators for the component, and the lower case letters represent the serial number

Revisions:

21-Nov-2001	Original
24-April-2002	Removed Yoke Stacking boxes becuase they are now being stacked outside Fermilab
01-July-2002	Added comment regarding Fermilab using LQXBzz for final assembly (333644)

This is the version agreed upon between FNAL and CERN

Weld Inspections on FNAL Q2a and Q2b Quadrupoles

Agreement with CERN Safety Requirements

The schedule of tests for qualification and for production of Fermilab Q2a and Q2b quadrupoles is consistent with the agreements reached between CERN, Fermilab, and the US LHC Accelerator Project Office on 19 April 2000 (meeting report dated 28 April 2000 issued by M. Bona,).

Three sets of tests are discussed below:

- **Table 1** lists the tests that support the qualification of weld materials and weld process. These tests were proposed by Fermilab in March and finalized in the meeting on 19 April 2000.
- **Table 2** lists the tests according to ASME Section IX for qualification and re-qualification of welders (both equipment and personnel). Welders that are inactive for a period of six months must be re-qualified through the tests listed in Table 2.
- **Table 3** lists the tests to be performed on each series production magnet. These tests support the requirements of ASME Section VIII and Fermilab rules for the operation of pressure vessels.

Qualification of the Weld Materials and Process

The qualification of the weld materials and weld process for the Fermilab Q2a and Q2b magnets takes an approach analogous to that used by Brookhaven National Laboratory (BNL) for the RHIC magnets and accepted by CERN for the BNL beam separation dipoles. Fermilab provided documents to CERN in March 2000 describing the design and analyzing the operational limits of the weld. These documents were accepted by CERN as stated in the report of the 19 April 2000 meeting between CERN and Fermilab.

Qualification testing will be performed on a mechanical model. The weld geometry and weld process are identical to that of prototype and production magnets. Coupons will be taken from the mechanical model and weld sample tests as described in the Table 1 will be conducted to support qualification of the weld materials and process.

In addition to the tests performed on the mechanical model, one of the prototypes will have strain gauges applied. The gauges will be applied before welding of the cold mass skin to verify the level of stress obtained after welding. Since the vertical gap between the two iron halves remains closed, the evolution of stresses during cool-down does not need to be monitored.

Table 1 Weld Qualification Tests: The tests are conducted according to standards used by FNAL. Test standards used by CERN, which are comparable but not necessarily identical, are listed for reference. Weld samples are taken from the mechanical model. All tests are conducted at room temperature unless otherwise noted.

Qualification Tests	CERN Standard (for reference only)	FNAL Standard	Note
Tests on Mechanical Model			
Visual inspection	EN 970 (test) ISO 5817 (acpt)	FNAL ES-369730	1
Delta ferrite test		AWS A 4.2 (test)	2
Tests on Weld Samples			
Visual examination (*macro-examination)*		ASME Sec. IX, QW-302.4 (test) ASME Sec. IX, QW-194 (acpt)	3
Transverse tensile test *300 K, 77 K, and 4.2 K*	EN 895 (test) EN10002-1 (acpt)	ASTM E 8M (test) ASME Sec IX, QW-153 (acpt)	4
Impact test *300 K, 77 K, and 4.2 K* *3 required in heat affected zone* *3 required in welded metal*	EN 875 (test) ISO 148 (test) EN 10045-1 (test)	ASTM E 23-96 (test) ASME Sec. VIII, UG-84 (acpt)	5
Fracture toughness test *300 K, 77 K, and 4.2 K*		ASTM E 1737-96 (test)	6
Radiographic (x-ray) test		ASME Sec. IX, QW-302.2 (test)	7

Notes on tests listed in Table 1 – Weld Qualification Tests

1. Visual inspection: Each pass of each weld will be visually inspected along its full length. Fermilab will specify the acceptance in a written engineering specification.

2. Delta ferrite test: This test was proposed by Fermilab to support qualification. AWS A 4.2 is a standard of the American Welding Society. Delta ferrite measurements are taken of the weld at discrete points along the magnet. Fermilab will establish a written standard for the spacing between discrete points and the maximum acceptable ferrite number for the GTAW process.

3. Visual examination: This test was proposed by Fermilab and required by ASME Sec. IX to check the depth of weld penetration.

4. Tensile test: This test was proposed by Fermilab to support qualification. Uniaxial tensile testing on welds at 300 K, 77 K, and 4 K will be conducted to determine the yield strength and ultimate tensile strength of the weldments. According to ASME Section IX (QW-153) the weld specimens must have an ultimate strength not less than the minimum specified strength of the base material. For 304 stainless steel, Table UHA gives a minimum required tensile strength of 550 MPa.

5. Impact test: This additional test was included by agreement between CERN and Fermilab. Charpy V-notch specimens will be impact tested at 300 K, 77 K, and 4.2 K. Three specimens from the weld and three from the heat affected zone will be tested at each temperature. According to UG-84, welded specimens must have a Charpy impact energy not less than the minimum specified impact energy of the base material. For a minimum tensile strength of 550 MPa, the required average impact energy of three samples is 27 J/cm^2 with a minimum impact energy of any one of the specimens of 20 J/cm^2.

6. Fracture toughness test: This test was proposed by Fermilab to support qualification at cryogenic temperatures. Notched specimens will be tested at 300 K, 77 K, and 4.2 K to characterize the toughness of the weld material. From the fracture mechanics analysis submitted to TIS (TD-00-025), we require a weld material with fracture toughness greater than 85 MPa $\sqrt{m}$.

7. Radiographic test: This test was added by Fermilab to further support qualification. The weld samples that will be taken from the mechanical model will be inspected radiographically. ASME Section IX will be used as a guide for the test and inspection of the samples. The radiographic inspector will be asked to identify rounded indications and linear indications (cracks, incomplete fusion, elongated inclusions). The inspector will be asked to estimate their sizes.

Welder Qualification and Re-qualification

Qualification and re-qualification of the welding equipment and personnel will be according to the requirements of ASME Section IX. Re-qualification is most often required due to a period of inactivity of six months or more, usually resulting from an interruption in production. Coupons will be taken from run-offs made during welder qualification (or re-qualification). Tests as described in the Table 2 will be conducted to support welder qualification or re-qualification.

Table 2 Welder qualification and re-qualification tests. The tests are conducted according to standards used by FNAL. Test standards used by CERN, which are comparable but not necessarily identical, are listed for reference. All tests are done at room temperature.

Welder Qualification Tests	CERN Standard (for reference only)	FNAL Standard	Note
Tests on Weld Samples			
Visual examination		ASME Sec. IX, QW - 302.4 (test) ASME Sec. IX, QW-194 (acpt)	1
Bend test	EN 910 (test) ISO 7438 (test)	ASME Sec IX QW-462.3 (b) (test) ASME Sec IX QW-163 (acpt)	2

Notes on tests listed in Table 2 – Welder Qualification Tests

1. Visual examination: This test is proposed by Fermilab and required by ASME Sec. IX to check the depth of weld penetration.

2. Bend test: This test is required by ASME Section IX to determine the degree of soundness and ductility of weld joints. ASME requires the bend specimens have no open defects in the weld or heat affected zone exceeding 1/8 in (3.2 mm), measured in any direction on the convex surface of the specimen after bending.

Production Testing

No destructive tests are required for the Q2a and Q2b magnets. The production welds will be tested as indicated in Table 3.

The four run-offs from each production magnet will be saved and archived. Each run-off will be approximately 150 mm in length along the weld and labeled with the magnet number and location. The run-offs will become included with the engineering file supplied with each magnet.

Table 3 Production tests on series Q2a and Q2b quadrupoles. The tests are conducted according to standards and procedures used by FNAL. Test standards used by CERN, which are comparable but not necessarily identical, are listed for reference. All tests are conducted at room temperature unless otherwise noted.

Production Tests	CERN Standard (for reference only)	FNAL Standard	Note
Tests on Delivered Units			
Visual inspection	EN 970 (test) ISO 5817 (acpt)	Fermilab ES-369730	1
Delta Ferrite Tests		AWS A 4.2 (test)	2
Leak check		Fermilab ES-107240	3
Pressure test		Fermilab ES&H 5034 ASME Sec. VIII , UG-100	4

Notes on tests listed in Table 3 – Production Tests

1. Visual inspection: Each pass of each weld will be inspected along its full length.

2. Delta ferrite test: This test was proposed by Fermilab to support qualification and will be conducted on each production unit. AWS A 4.2 is a standard of the American Welding Society. Delta ferrite measurements will be taken of the weld at discrete points along the magnet. Fermilab will establish a written standard for the spacing between discrete points and the maximum acceptable ferrite number for the GTAW process.

3. Leak check: This test is required by Fermilab.

4. Pressure test: This test is required by ASME Section VIII Division 1. On 1 July 1999 ASME reduced the pneumatic pressure test requirement from 1.25 to 1.1 times design pressure. Fermilab will continue to pneumatically test each production cold mass to 1.25 design pressure to remain consistent with current FNAL and CERN requirements.

CERN
CH-1211 Geneva 23
Switzerland

the
Large
Hadron
Collider
project

LHC Project Document No.
LHC-LQX-ES-0008 rev 0.1

CERN Div./Group or Supplier/Contractor Document No.
TD / FNAL / USA

EDMS Document No.

Date: 12 December 2002

Acceptance Specification

ACCEPTANCE PLAN FOR LQXB

Abstract

This specification establishes the requirements and procedure for qualifying an LQXB for use in LHC.

Prepared by :	***Reviewed by :***	***Approved by :***
J. Kerby	**J. Strait**	**[Name]**
FNAL	FNAL	[division/institute]
Kerby@fnal.gov	Strait@fnal.gov	[electronic.mail]

History of Changes

Rev. No.	*Date*	*Pages*	*Description of Changes*
0.0	2002-01-14	All	Initial draft
0.1	2002-03-12	All	Acceptance process reviewed

Table of Contents

1. ACCEPTANCE PROCESS

1.1 REVIEW STRUCTURE

There are several stages to the process of accepting an LQXB magnet for use in the LHC. First there is a "pre-acceptance" process in which the magnet is evaluated during the manufacturing process. Here problems are identified while there is still an opportunity to correct them. Second is the formal acceptance plan where a magnet review board determines whether the magnet meets the requirements agreed upon by CERN. Next, the USLHC and the CERN management consider the magnet review board's recommendation and decide whether the magnet will be shipped to CERN. Finally, on delivery to CERN, there a subset of the acceptance tests will be performed again to insure that the magnet was not damaged during shipment.

1.2 MAGNET REVIEW BOARD

The FNAL-LHC Project will create a magnet review board. The purpose of this board is to review data from the production process and make recommendations as to the worthiness of this magnet for LHC operation. This board will be convened as necessary, either in person or electronically.

Members of the review board will include the FNAL-LHC Project Manager, FNAL-LHC AP Manager, FNAL-LHC Test Manager, FNAL-LHC Cold Mass Manager, FNAL-LHC Cryostat Manager, and FNAL-LHC Integration Manager or their designees. Other personnel may be added on an ad hoc basis as needed.

Responsibilities among each person are as follows:

- FNAL-LHC Project Manager—generation of report, summarize conclusions of the board, forwarding recommendation to US-LHC
- Cold Mass Manager—reports 'cold mass' results from Acceptance Criteria (see below, i.e. warm) HiPot and electrical results, mechanical measurements
- Cryostat Manager—reports 'cryostat' results, i.e. pressure tests, room temperature leak checks, safety documentation, dimensional checks, preparation for shipping
- Test Manager—reports 'test' results, i.e. warm and cold harmonics, quench results, other test results
- Integration Manager—reports 'integration' results, i.e. electrical continuity checks, successful bus & instrumentation routing.
- AP Manager-reports i.e. studies of specific harmonic and alignment data, as needed

1.3 PRE-ACCEPTANCE

There are three components to this process. First is the adherence to the LQXB magnet travelers which provide a detailed step by step instruction of the magnet construction. At the completion of each step, the traveler is signed by the Cold Mass manager or his designee. If the step is not completed as planned, e.g. measurement-validated step is out of tolerance, then a descrepancy report is written and signed by the Cold Mass manager or his deisgnee. The purpose of these exceptions is to acknowledge a deviation from the process that will not affect the final magnet acceptance. The Cold Mass manager may convene the Magnet Review Board to discuss the impact of a descrepacny.

The second component is an evaluation of the room temperature collared coil harmonics. Field quality data, measured at room temperature, are evaluated when the collared coil is complete. The FNAL-LHC Test Manager determines, based on the values for this magnet and trends from this and all previous collared coils, if the collared coil is accepted or if the FNAL-LHC Magnet Review Board shall be convened to evaluate the data. This determination is transmitted to the FNAL project manager.

The third component is an evaluation of the alignment of the two MQXB that make up the LQXB module. Room temperature Single Stretch Wire (SSW) measurements are performed on the individual MQXB magnets to determine their relative magnetic axes. The FNAL-LHC Test Manager determines, based on the requirements from the IR quad reference alignment table [16] if the alignment is acceptable or if the FNAL-LHC Magnet Review Board shall be convened to evaluate the data. This determination is transmitted to the FNAL project manager.

1.4 REVIEW BY ACCEPTANCE BOARD

Section 2 outlines and discusses the agreed-upon acceptance criteria for the magnets. The board is responsible for reviewing the construction and test data to determine if the completed magnet meets these criteria. In all cases the board will recommend to the Fermilab USLHC Project leader the disposition of the magnet.

The review, including an evaluation from the FNAL-LHC Project Manager as to whether the magnet is suitable for use in LHC, any exceptions, any restrictions on use, and the basis of the evaluation, is forwarded to the US-LHC Project Office for review

The LHC Project Office sends the report, with any additional comments it may add, to the official CERN contact person for the interaction regions. The magnet may be shipped when the CERN contact person for the interaction regions indicated his approval.

1.5 ACCEPTANCE BY FERMILAB OF CERN SUPPLIED COMPONENTS

The completion of the LQXB requires the integration of several CERN supplied components. Components include, quench protection strip heater, instrumentation wires, insulated corrector bus work, thermometers, and a MCBX orbit corrector. The specifications of these components are covered through control documents in the CERN Document Control. For instrumentation wires, corrector bus work and quecch protection heaters, continuity and voltage standoff (hipot) will be checked during the course of the LQXB manufacturing. The room temperature resistance of the CERN supplied thermometers will be performed prior to installation and compared to traveller.

Resistance will be monitored during the construction and test process. Finally, mechanical and electrical tests will be performed on the MCBX corrector prior to installation.

1.6 MAGNET RECEIPT AT CERN

Upon arrival at CERN, a set of measurements and checks will be performed promptly, to verify the integrity of the magnet following shipment. These tests, which are specified in section 3, generally involve measurements which can be compared with specified tolerance bands. If any measurements are out of tolerance, or there are any indications of damage in transit, the disposition of the magnet will be discussed among: the official CERN contacts for the US Project and for the Insertions, the PMO, and FNAL Magnet acceptance board FNAL-LHC Project Manager, and others as appropriate. Disposition may include return of the magnet to FNAL for repair and rework, repair done at CERN by FNAL or CERN personnel, or acceptance by CERN of the magnet with the noted deviations. CERN will document its acceptance of the magnet by memo (paper or e-mail) from the official CERN contact. Once CERN has accepted the magnet, responsibility for it will be considered to be formally transferred to CERN.

2. ACCEPTANCE CRITERIA

Acceptance has been broken down in twp general categories: room temperature test and tests in liquid helium. For each criterion, there is a requirement, a reference to where the requirement is called out (usually in a previous specification), a location of the procedure used to satisfy the requirement and a summary of the procedure. Note these tests are performed the last time they can be performed on the magnet. Thus, some of the checks occur during magnet construction while others occur just before the magnet is placed in the shipping container.

2.1 ROOM TEMPERATURE MEASUREMENTS

2.1.1 MQXB MECHANICAL TWIST AND STRAIGHTNESS

Requirement: Less than 1 mR/5 m twist, 100 μm/5 m straightness

Procedure: See Cold Mass Final Assembly Traveller [9]

Procedure summary: Warm MQXB is laid on granite table. For twist, Using leveling fixture keyed to Skin alignment key, determine angle of keys relative gravity. For straightness, estimate maximum bow from a straight edge at the horizontal position.

Reference: Table 4 LHC-LQX-ES-0002 [1]

2.1.2 MQXB COIL RINGING

Requirement: No evidence of coil to coil breakdown.

Procedure: See End Clamp Installation Traveller [10]

Procedure summary: Using Fermilab coil ringing device, discharge capacitor bank charged to 500 volts unto each magnet quadrant and record current and voltage trace. Compare trace to standard. Look for evidence of turn to turn and coil to ground breakdown

Reference: Section 3.3 LHC-LQX-ES-0002 [1]

2.1.3 THERMOMETER AND WARM UP HEATER INSTALLATION

Requirement: Thermometers and heaters installed properly

Procedure: Module Assembly traveller [11]

Procedure summary: Prior to assembly of end comes, check RTD resistance relative to RTD traveller, inspect heaters and thermometers for appropriate placement, strain relief

Reference: Section 4.2 LHC-LQX-ES-0007 [7], LHC-QIT-ES-0002 [8]

2.1.4 BUS WORK CHECKOUT

Requirements: Bus work properly insulated, strain relieved

Procedure: Module Assembly Traveler [11]

Procedure summary: Prior to assembling end domes, inspect bus for proper installation including solder joints and insulation

Reference: Section 4.2 LHC-LQX-ES-0007 [7]

2.1.5 ROOM TEMPERATURE HIPOT

Requirement: In air or bagged in dry N2, Quadrant to quadrant (prior to quadrant busing), 3 kV.

For completed LQXB 1) with coil shorted to ground, hipot heater to ground 5kV, 2) with heater shorted to ground, hipot heater to ground 5 kV. Leakage current less than 5μA and no breakover.

Procedure: See Cold Mass Final Assembly Traveller [9]

Procedure summary: Follow hipot safety procedure outlined in traveler.

Reference: Section 3.4 Voltage limits LHC-LQX-ES-0002 [1]

2.1.6 ROOM TEMPERATURE ELECTRICAL CHECKOUT

Requirements:	Instrumentation wires are properly labeled, correct wire gauge, correctly wired to hypertronics connector, proper continuity
Procedure:	Module Assembly Traveler [11]
Procedure summary:	Verify wires are properly labeled. Voltage taps and heaters give appropriate values. Insure wires are properly bundled and strain-relieved.
Reference:	Section 3.3 LHC-LQX-ES-0002 [1], Section 4.2 LHC-LQX-ES-0007 [7]

2.1.7 LQXB STRAIGHTNESS AND SAG

Requirement:	Measure Straightness of Cold Mass Prior to Installation to Cryostat
Procedure:	See Cold Mass Final Assembly Traveller [9]
Procedure summary:	Warm LQXB is laid on table using Cryostat support structure. Measure the position of the relative transerve location of the cold mass as a function of longitudinal posiition
Reference:	Table 4 LHC-LQX-ES-0002 [1]

2.1.8 PRESSURE TEST DOCUMENTATION

Requirement:	Test pressure of 1.25 times the design pressure. The design pressure is 20 bar so the test pressure is 25 bar or approximately 375 psi (2.5 Mpa).
Procedure:	Section 5034 of the Fermilab ES&H Manual [13] and UG-100 of the ASME Code
Procedure Summary:	Perform test after normal working hours and only personnel directly involved with the test will be present. Use dry nitrogen and increase the pressure in small increments until the final pressure is reached. Hold this pressure for 30 seconds and the release pressure.
Reference:	Section 2.6 LHC Interaction Region Quadrupole Engineering Note for Complete Magnet Testing at Fermilab [12]

2.1.9 LEAK CHECK DOCUMENTATION

Requirement:	Follow requirements in Fermilab Specification ES-107240 [2]
Procedure:	Cryostat Assembly Traveller [14]
Procedure summary:	Each component will be leak check as part of incoming QC. Assembly will be leak checked after all welding is complete.
Reference:	Fermilab Specification ES-107240 [2]

2.1.10 CRYOSTAT SAFETY DOCUMENTATION

Requirement:	Design according to ASME BPV Section VIII, Division I and must meet all applicable Fermilab safety codes.
Procedure:	See Engineering Note [12]
Procedure summary:	See Engineering note [12]
Reference:	ASME BPV

2.1.11 PIPE ASSEMBLY DOCUMENTATION

Requirement:	See LHC-LQX-ES-0007 [7] and reference drawings
Procedure:	See Cryostat Assembly Traveller
Procedure summary:	X, Y, Z positions of pipes measured per above drawings.
Reference:	LHC-LQX-ES-0007 [7] See Fermilab drawings [3,4,5]: For Q1: 5520-ME-390265 For Q2: 5520-ME-390266 For Q3: 5520-ME-390267

2.1.12 WARM CRYOSTAT TO MAGNETIC AXIS REFERENCE

Requirements:	Limits of cold mass to cryostat alignment driven by pipes in x,z: 0.5 mm; y position limits: 3 mm
Procedure:	Run Plan [15]
Procedure Summary:	SSW measurements of magnetic axis to external fiducials warm.
Reference:	Permutation of Reference alignment table [16]. Also see LHC-LQX-ES-0006 [6] Table 4

2.2 COLD TEST

2.2.1 COLD INSTRUMENTATION CHECK OUT

Requirement:	Instrumentation wires have proper continuity, no shorts to ground
Procedure:	LQXB Test run plan [15]
Procedure summary:	On test stand, all instrumentation wires are checked on the test stand for proper continuity. Resistance to ground is measured.
Reference:	Section 3.3 LHC-LQX-ES-0002 [1]

2.2.2 COLD HEATER CHECKOUT

Requirements:	Heater circuits have proper resistance, quenches all quadrants
Procedure:	Lqxb Test runplan [15]
Procedure summary:	Measure cold resistance and compare to nominal.. With no magnet excitation current discharge heaters with heater firing units. Using data logger signals verify time constants, no arc over to ground. At 3000 amps, initiate quench with heaters (or manual trip with extraction circuit delay) Verify that there is resistive voltage in all 4 quadrants within 150 ms of heater firing.
Reference:	Section 3.2 LHC-LQX-ES-0002 [1]

2.2.3 COLD ELECTRICAL HIPOT

Requirement:	On test stand, in liquid helium, coil to ground/heater and heater to ground/coil can withstand 1.4 kV voltage difference with leakage current less than 5μA
Procedure:	Test run plan [15]
Procedure summary:	Follow hipot safety procedure outlined in pretest.
Reference:	Section 3.4 Voltage limits LHC-LQX-ES-0002 [1]

2.2.4 NO QUENCHING UP TO AND INCLUDING OPERATING GRADIENT (AFTER TRAINING)

Requirement:	Magnet reaches 230T/m during first 1.9 K thermal cycle, reaches 220T/m on 2nd and successive thermal cycles without quenching
Procedure:	LQXB Run Plan [15]

Procedure summary:	During first superfluid test in LQXB assembly, magnet reaches (230 T/m)12785 A as a result of training program. On second thermal cycle the magnet is ramped to 12205 A (220 T/m) without a spontaneous quench
Reference:	Table 2 LHC-LQX-ES-0002 [1]

2.2.5 FULL ENERGY TRIP

Requirement:	As a result of a quench, hot spot temperature less than 400 K
Procedure:	LQXB Run plan [15]
Procedure summary:	Execute full energy manual trip. At 12000 amps (which corresponds to approximately 215 T/m) Power supply is phased back, both heater circuits are energized. No external extraction circuits. Determine the quench integral from the on line data loggers. MIITs value less than 15.
Reference:	Section 3.2 LHC-LQX-ES-0002 [1]

2.2.6 NO TRAINING DEGRADATION AFTER FULL ENERGY DEPOSITION TRIP (SEE ABOVE)

Requirement:	Magnet reaches 220 T/m after full energy deposition quench
Procedure:	Run Plan [15]
Procedure summary:	In superfluid, magnet energy is dissipated through a “full energy deposition quench”, a 12kA manual trip of the system. The power supply is phased off, the heaters are fired. There is no energy extraction circuit. Then magnet is ramped to 12205 A (220 T/m) without quench.
Reference:	CERN-KEK-US collaboration minutes April 2001

2.2.7 TRANSFER FUNCTION

Requirement:	Gradient /excitation current correlation
Procedure:	LQXB Run plan [15]
Procedure summary:	Measure the field strength using the single stretch wire system, at 11345A Measured integrated gradient should be 1127 +/- 2 T (205 T/m, 5.5 m).
Reference:	Table 2, Figure 3 LHC-LQX-ES-0002 [1]

2.2.8 INTEGRATED COLD HARMONICS

Requirements:	Harmonics fall within acceptance table limits.

Procedure:	Run plan [15]
Procedure summary:	During cold testing, measure harmonics. up to the b10, a10 during continous ramp cycle and “DC” at gradients: 12.3 T/m, 100 T/m, 185 T/m, 200 T/m, 215 T/m. At 12.3 T/m and 200 T/m compare results to acceptance limits shown on table . Limits are defined as: db + 2 σ(b), no discussion; db + 2 σ(b) to db + 3 σ(b) , report; > db + 3 σ(b), review with AP.
Reference:	Table 3 LHC-LQX-ES-0002 [1] and Integrated Cold Harmonics Acceptance Table [1], [15]

2.2.9 COLD ALIGNMENT

Requirements:	Limits of cold mass to cryostat alignment driven by pipes in x,z: 0.5 mm; y position limits: 3 mm
Procedure:	Run Plan [15]
Procedure Summary:	SSW measurements of magnetic axis to external fiducials cold.
Reference:	Permutation of Reference alignment table [16]. Also see LHC-LQX-ES-0006 [6] Table 4

3. ACCEPTANCE CRITERIA AFTER ARRIVAL AT CERN

The following list is a summary of the acceptance tests to be performed at CERN following shipment. These test are in three categories: physical inspection, mechanical measurements and electrical measurements

3.1 SHIPPING DATA

Physical inspection of shipping container for signs of damage during transit.
If container is installed with instrumentation, such as an accelerometer, hygrometer or thermometer, instruments should be sent back to Fermilab for evaluation. FNAL will summarize the data in a report to CERN. At the present time, acceptance criteria for these parameters have not been established.

3.2 MECHANICAL MEASUREMENTS

Pipe locations should be re-measured, and shown to be in accordance to acceptance criterion 2.2.4

3.3 ELECTRICAL MEASUREMENTS

The follow set of measurement are to be performed at room temperature, either in air or in dry N2, and compared to provided acceptance bands.

a) Continuity of all instrumentation wires. Verify using “2-wire” technique that wires are properly connected; feed through wires show continuity from one connector to another, heater wires attached to heaters etc. Use interconnect wiring diagrams as shown in Interface specification[7]

b) Hipot requirements: In room temperature N2 or air
Coils shorted to ground, heaters to ground 2.5 kV, 50 μA leakage
Heaters shorted to ground, coil to ground 2.5 kV, 50 μA leakage

c) Resistance to ground
Temperature sensors >20MΩ
Warmup heater >20 MΩ

c) Resistannce/inductance/Q measurements
Using coil voltage taps as defined in [7] measure whole coil, Half coil resistances.
Values should agree with nominal to +/- .05 Ω

Thermometer resistance +/-5 Ω relative to calibration value

Magnet inductance +/- 0. 3 mH of nominal

Q factor +/- 0.3 of nominal

4. REFERENCES

[1] LHC Functional Specification, "Inner Triplet Quadrupole MQXB," LHC-LQX-ES-0002.

[2] Fermilab Specification ES-107240
http://tdserver1.fnal.gov/project/uslhc/public/leaktest/list.pdf.

[3] LHC IRQ Cryostat Q2 Interface and Assembly, FNAL Drawing number 5520-ME-390265
http://tdserver1.fnal.gov/nicol/lhc_irq_cryostat/drawings/index.html

[4] LHC IRQ Cryostat Q2 Interface and Assembly, FNAL Drawing number 5520-ME-390266
http://tdserver1.fnal.gov/nicol/lhc_irq_cryostat/drawings/index.html

[5] LHC IRQ Cryostat Q2 Interface and Assembly, FNAL Drawing number 5520-ME-390267
http://tdserver1.fnal.gov/nicol/lhc_irq_cryostat/drawings/index.html

[6] LHC Functional Specification, "Inner Triplet Quadrupole Helium Vessel LMQXB and Cryostat Assembly LQXB," LHC-LQX-ES-0006, rev 0.3, 12 December 2001

[7] LHC Interface Specification, "Inner Triplet Quadrupole Helium Vessel LMQXB and Cryostat Assembly LQXB," LHC-LQX-ES-0007, rev 0.3, 12 December 2001

[8] Engineeering Specification, "Installation Guide for LHC Cryogenic Thermometers," LHC-QIT-ES-0002

[9] Cold Mass Final Assembly Traveller (Specification #5520-TR-333498)
http://tdserver1.fnal.gov/project/uslhc/public/travelers/list.pdf

[10] End Clamp Installation Traveller (Specification #5520-TR-333496)
http://tdserver1.fnal.gov/project/uslhc/public/travelers/list.pdf

[11] Module Assembly Traveller (Specification #5520-TR-333643)
http://tdserver1.fnal.gov/project/uslhc/public/travelers/list.pdf

[12] LHC Interaction Region Quadrupole Engineering Note for Complete Magnet Testing at Fermilab, March 8, 2001
http://tdserver1.fnal.gov/nicol/lhc_irq_cryostat/engr_note/index.html

[13] Fermilab ES&H Manual,
http://www-esh.fnal.gov/home/esh_home_page.page?this_page=800.

[14] Cryostat Assembly Traveler (Specification #5520-TR-333644)
http://tdserver1.fnal.gov/project/uslhc/public/travelers/list.pdf.

[15] LQXB Test Plan
http://tdserver1.fnal.gov/project/uslhc/public/**runplan/rep_lmqxb01.pdf**

[16] IR Quadrupole Reference Alignment Table, http://www-ap.fnal.gov/lhc/meetings/workshop99.html.

[17] Harmonics Acceptance Table
http://tdserver1.fnal.gov/project/uslhc/public/**harmonicstable / acceptance.pdf**

LMQXB01 Test Plan

August 14, 2002

0.1 Outline

Test Cycle I

In this test cycle all the procedures will be done for Q2A and Q2B separately.

- Magnetic measurements
- Room Temperature Pretest and Cool down
- Between 4.5K and 1.9K

  Pre-Current excitation Checkout
- At 1.9K Operation

  3000 amp and 670 amp tfn test

  Quench training (to get above 230 T/m)

  Magnetic measurements

Test Cycle II

In this test cycle Q2A and Q2B will be connected to the power leads as a single Q2 unit

- Between 4.5K and 1.9K

  Pre-Current excitation Checkout
- At 1.9K Operation

  3000 amp tfn test

  Quench varification (to get to 220 T/m without quenching)

  Ramp rate studies - one quench at 300 A/sec
- Full Energy deposition, quench the magnet: Re-verification
- Magnetic measurements (at room temp.)

0.2 Test cycle I

0.2.1 Magnetic measurements

1. The magnet is located at Stand 4
   (a) Harmonics and stretched wire measurements (details of the measurements will be determined later)

0.2.2 Room Temperature Pretest/Cooldown

1. Follow present procedures for voltage taps, thermometer, and heater validation. Procedures include:
   (a) 4 wire heater resistance, system resistance for two heater circuits.
2. Cool down to 4.5 K , 1.1 ATM with unrestricted cooldown following Stand 4 cool-down procedure.

0.2.3 During 4.5 K to 1.9 K cool down

1. Cold electrical tests prior to magnet testing
   (a) Check magnet resistance to ground.
   (b) Hi pot (1.1 ATM helium). Maximum volts should not exceed $V_{max} = 1400V$ value.
   (c) Protect magnet with a 60 mΩ dump resistor. $I_{max} * R_{dump} \leq 1000V$
   (d) Connect Q2A to the power leads
   (e) Heater Pretests
      i. Configure QLM to fire heater with 1 sec dump firing delay
      ii. Check outer heater and heater system resistance using 4 wire techniques. System capacitance should be set to approximately 7 mF.
      iii. Verify that outer heaters are connected to SHFU's.
      iv. Fire outer heaters from HFU gui. Verify RC, V heaters, I heaters from data logger plots

(f) Disable Digital QDC (or set to high thresholds)

(g) Balance quench detection circuitry for analog QDC

  i. Set dump delay to 0 sec

  ii. sawtooth ramps between 50 A and 450 A at 100 A/sec and 300A/s

  iii. Establish thresholds based on observed noise versus anticipated signals.

(h) Balance quench detection circuit for DQDC

(i) Set dump delay to 25msec and the heater delay to 0msec. Manual trip at 1000 A. **Every single analog QDC platform has to be checked separately. Power supply, dump switch, heater and interlock respond should follow the proper quench logic.** Delay heater firing to 1 sec dump delay = 0 sec. Do another manual trip and check L/R, look at all data logger voltage signals; compare V_{max} to $I * R_{dump}$

0.2.4 At 1.9K Operation

1. Quench Heater Protection test

   (a) t_{fn} test. It must be performed for both heater circuits

     i. Set dump resistor delay to 0 ms, no heater delay, no power supply phase off delay

     ii. At 3000A magnet current, fire the SHFU at 900V and check that the t_{fn} value is less than 200 ms and all four quadrant are quenched

     iii. Check quench logic signal for proper quench timing sequence

   (b) Heater operation at injection (670A)

     i. Delay the dump to 1sec

     ii. At 670 A fire SHFU at 900V (all of them). Check t_{fn}

2. Quench training

   With ramp rate = 20 A/sec, train the magnet. If the quench current produce more than 230 T/m field gradient do not do more quenches.

3. Magnetic measurements

   The default ramp rate is 20 A/sec.

   The nominal data set is 25 rotations of the coil.

   All measurement sequences should begin with a "cleansing" quench at $\sim$ 10000A. A cleansing quench is done by firing the magnet heaters with magnet current high enough to produce a small remnant field.

   (a) Set the heater delay to 0 msec, dump delay to 0 msec, and dump resistance to 60 mΩ.

   (b) Determine the minimum magnet current for a cleansing quench: check the effect of a cleansing quench at 10000 A by checking the remnant magnetic field. If the remnant field is substantial increase the current and quench the magnet again. Repeat this procedure until the minimum current is found. Use this value of the current for all cleasing quenches needed for this test plan.

   (c) Take harmonics and stretched wire measurements (details of the measurements will be determined later)

0.2.5 Connect Q2B to power leads and repeat tests described in 0.2.3 and 0.2.4.

0.3 Test cycle II

Connect Q2A and Q2B to the power leads as a single Q2 unit

0.3.1 Magnetic measurements

1. At Stand 4

   (a) Take harmonics and stretched wire measurements (details of the measurements will be determined later)

0.3.2 During 4.5 K to 1.9 K cool down

1. Cold electrical tests prior to magnet testing

   (a) Check magnet resistance to ground.

   (b) Hi pot (1.1 ATM helium). Maximum volts should not exceed V_{max} value (to be determined).

   (c) Protect magnet with a 60 mΩ dump resistor. $I_{max} * R_{dump} \leq 1000V$

   (d) Repeat procedures from 0.2.3 1f through 1i.

   (e) Set dump delay to 25msec and the heater delay to 0msec. Manual trip at 1000 A. **Every single analog QDC platform has to be checked separately. Power supply, dump switch, heater and interlock respond should follow the proper quench logic.**

0.3.3 At 1.9K Operation

1. Quench Heater Protection test

   (a) Set dump resistor delay to 0 ms, no heater delay, no power supply phase off delay

   (b) At 3000A magnet current, fire the SHFU at 900V and check that the t_{fn} value is less than 200 ms and all four quadrant are quenched

   (c) Check quench logic signal for proper quench timing sequence

2. Quench Training

   With ramp rate = 20 A/sec ramp the magnet up to 220 T/m and down to 0. If the magnet quenches repeat the above test.

3. RAMP RATE dependence studies.

   Ramp to quench at 300 A/s,

4. Magnetic measurements

   Repeat Test cycle I procedures, as desired.

5. Heater studies

   (a) For heater study the default setting for the dump resistor delay is 1 s, no heater delay, no power supply phase off delay. All 4 heater circuits are in use.

   (b) Set SHFU to 900V voltage value. Ramp the magnet up to 8000A, 10000A, 12000A and initiate a manual trip.

   (c) Disconnect the heaters from Q2A. Set SHFU for Q2B to 900V. Ramp the magnet to 6000A, 8000A, 10000A, 12000A and initiate a manual trip.

6. Ramp up the current untill the magnet reach 220 T/m with 20 A/s ramp rate. If the magnet doesn't quench slowly ramp down the PS.

7. Warm magnet measurements

   (a) Take harmonics and stretched wire measurements (details of the measurements will be determined later)

Fermi National Accelerator Laboratory
Batavia, IL 60510

LARGE HADRON COLLIDER
FINAL COLD MASS ASSEMBLY TRAVELER

Reference Drawing(s)
Final Cold Mass Assembly
5520-ME-369655

9/26/02 60

Budget Code: LPT	**Project Code:** LHC
Released by: John J. Szostak	**Date:** ~~11/6/01~~ 11/6/01
Prepared by: J. Larson, M. Cullen, J. Szostak	

Title	Signature	Date
TD / E&F Process Engineering	Bob Jensen — **Bob Jensen / Designee**	11/6/01
TD / LHC Production Supervisor	**Jim Rife / Designee**	11-6-01
TD / LHC Production Engineer	Rodger B — **Rodger Bossert / Designee**	11/6/01
TD / LHC Program Manager	**Jim Kerby / Designee**	11/6/01

Revision Page

Revision	Step No.	Revision Description	TRR No.	Date
None	N/A	Initial Release	N/A	12/12/00
A	3.0	Added Picture of Heater Schematic.	1282	11/6/01
	4.6	Deleted Step. No Voltage Taps.		
	4.7	Deleted Step.		
	4.8	Deleted Step.		
	6.3	Added Note from Step 6.5. Updated Engineering Specification to (ES-369871).		
	6.4	Deleted Step.		
	6.5	Deleted Step.		
	6.7	Deleted Step.		
	7.2	Deleted Step. No Hipot necessary.		
	7.2	Added Step. "Verify torque on Pre-Load Bolts as per (ES-369871)".		
	8.6	New part number. Replaced (MD-344922) with (MD-369844).		
	8.11	Added Step. "Install Springboard Assembly (MC-369842 & MC-369843) onto the Cold Mass Assembly. Wrap the Springboard Assemblies in Kapton".		
	9.1	Deleted Step. No Strain Gauges.		
	9.2	Deleted Step. No Voltage Taps.		
	9.3	Deleted Step. No Strip Heaters.		
	9.5	Modified Step. Changed HiPot Table. Heaters grounded for Coil to Ground check. Coil grounded for Heaters to Ground check. Added Pictures.		
	9.7	Deleted Step. No Ring performed.		
	10.0 – 11.0	Steps added as per Jim Kerby.		

Ensure appropriate memos and specific instructions are placed with the traveler before issuing the sub traveler binder to production.

1.0 General Notes

1.1 White (Lint Free) Gloves (Fermi stock 2250-1800) or Surgical Latex Gloves (Fermi stock 2250-2494) shall be worn by all personnel when handling all product parts after the parts have been prepared/cleaned.

1.2 All steps that require a sign-off shall include the Technician/Inspectors first initial and full last name.

1.3 No erasures or white out will be permitted to any documentation. All incorrectly entered data shall be corrected by placing a single line through the error, initial and date the error before adding the correct data.

1.4 All Discrepancy Reports issued shall be recorded in the left margin next to the applicable step.

1.5 All personnel performing steps in this traveler must have documented training for this traveler and associated operating procedures.

1.6 Personnel shall perform all tasks in accordance with current applicable ES&H guidelines and those specified within the step.

1.7 Cover the product/assembly with Green Herculite (Fermi stock 1740-0100) when not being serviced or assembled.

2.0 Parts Kit List

2.1 Attach the completed Parts Kit for this production operation to this traveler. Ensure that the serial number on the Parts Kit matches the serial number of this traveler. Verify that the Parts Kit received is complete.

John J. Szostek
Process Engineering/Designee

11/6/01
Date

3.0 Cold Mass Final Assembly Preparation

MQXB Production Magnet Strip Heater Schematic

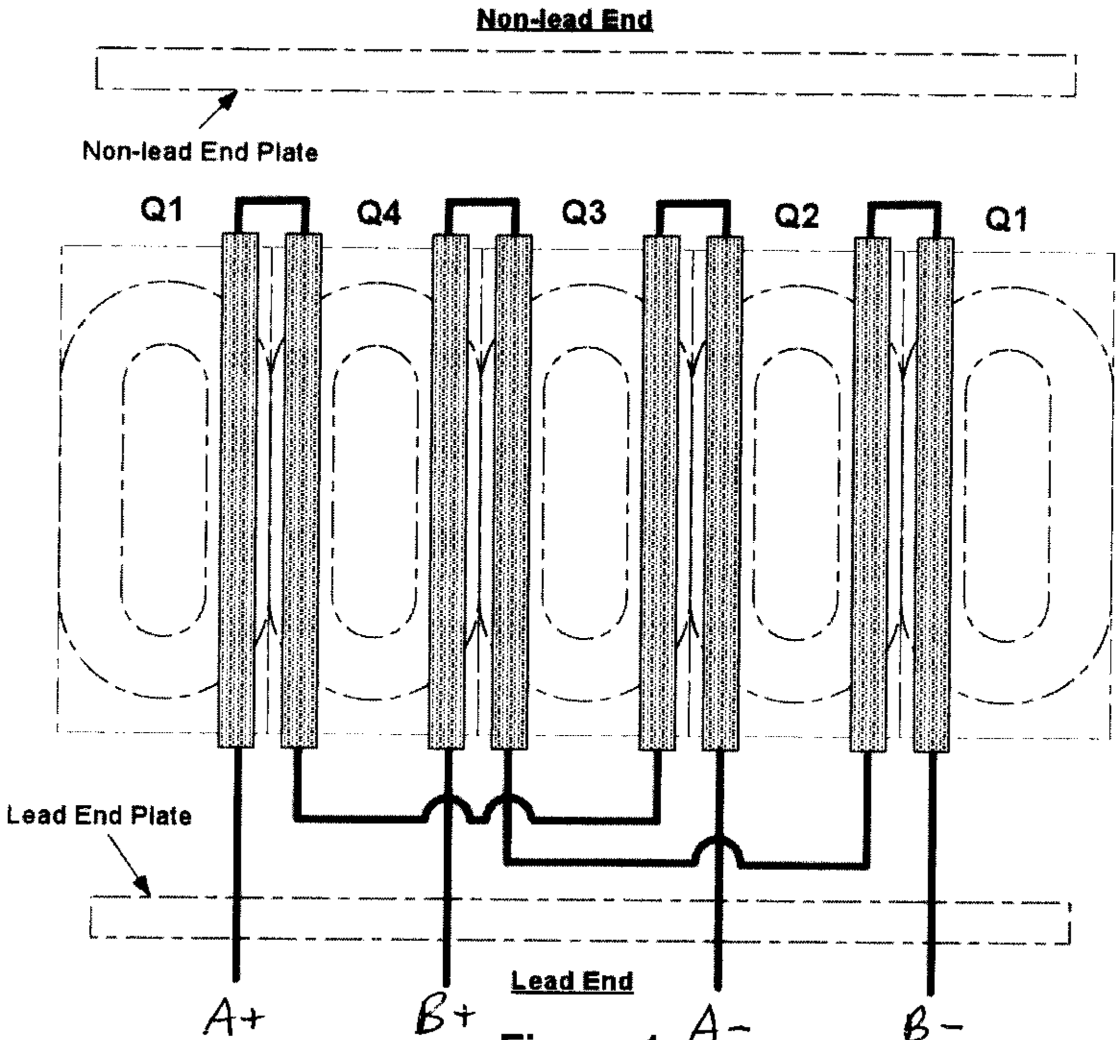


Figure 1

DR# Ф270

TRR# 1293

3.1 Install the Jumper Wires (length as required) (MA-369833) on the Heater Strips at the NON-Lead End as per Figures 1 & 2.

D Howld
Technician(s)

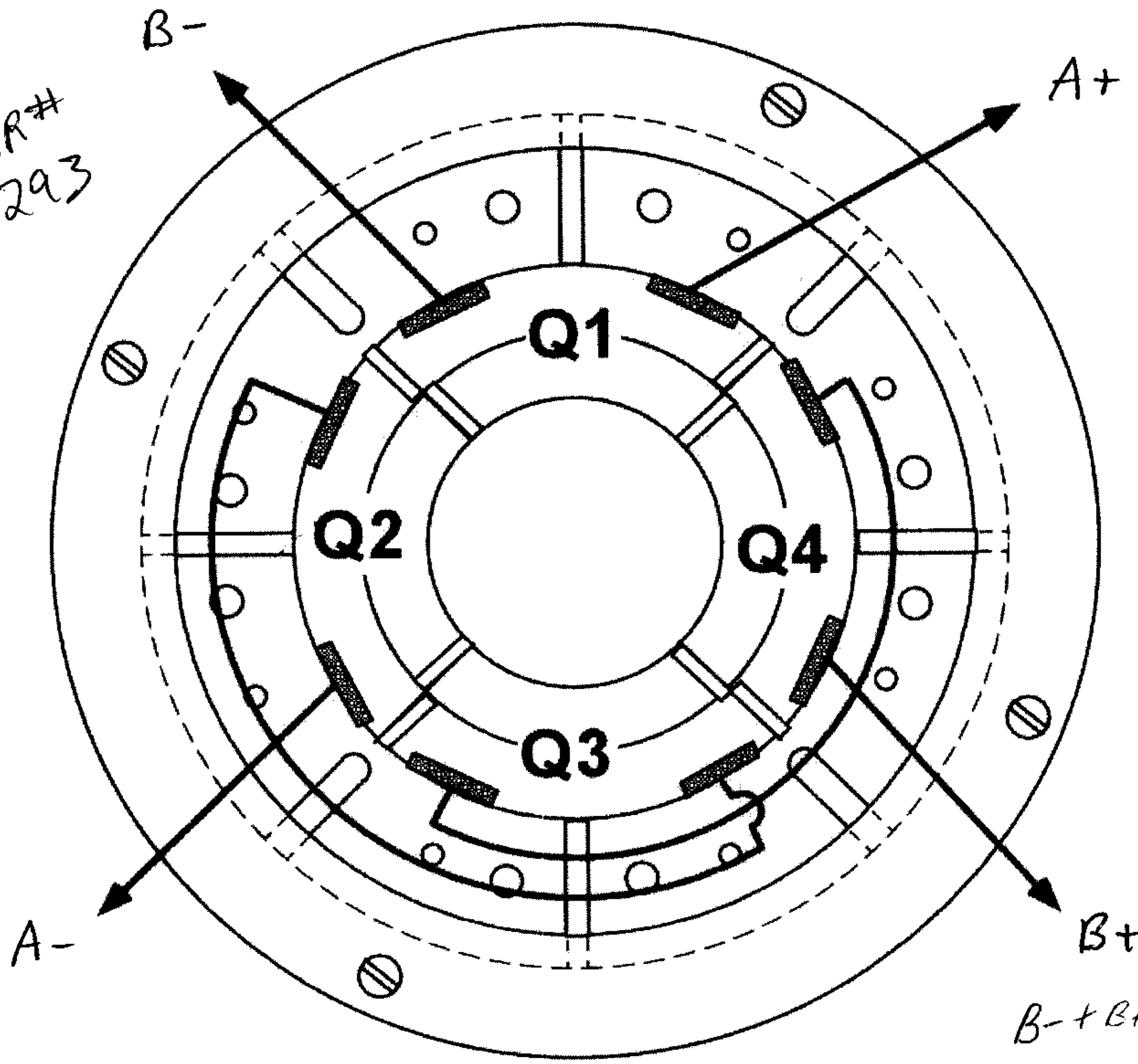
11/9/01
Date

3.2 Install Power Wires (19 meters) and Label per fig. 1 & 2 and Jumper Wires (length as required) (MA-369833) on the Heater Strips at the Lead End as per Figures 1 & 2.

Technician(s)

11-12-01
Date

TRR#
1293



B- + B+ 19.883
A+ + A- - 19.884

LHCIRQ Lead End Strip Heater Wiring Layout
Figure 2

TRR#
1318

3.3 Clean the entire Cold Mass with a Vacuum, Isopropyl Alcohol (Fermi stock 1920-0300) and Kimwipes (Fermi stock 1660-2500) or equivalent.

Technician(s) ______

Date 11-12-01

3.4 Insert the Heater Strips into notch and cover with Green Putty (MA-103930).

Technician(s) ______

Date 11-12-01

3.5 Verify that all Quadrant Leads are properly insulated.

Technician(s) ______

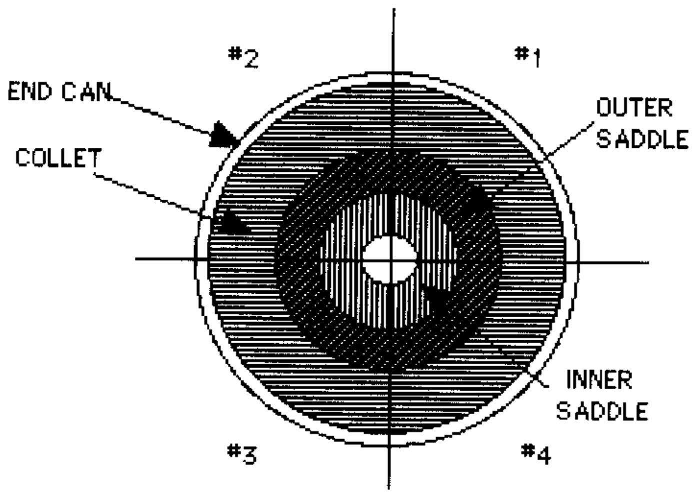
Date 11-12-01

4.0 Bullet Pressure Plate Installation

4.1 Shim the Lead End Inner and Outer Saddles until they are flush, using 5 mil adhesive backed Kapton or equivalent and G-11CR Lead End Saddle Shim Stock (MD-369818 (Inner) & MD-369819 (Outer)) or equivalent.

D Murphy
Technician(s)

11-21-01
Date



VIEW FROM LEAD END
LOOKING TOWARD RETURN END

4.2 Install the Lead End Full Preload Plate (MB-369060).

D Murphy
Technician(s)

11-21-01
Date

4.3 Shim the Non-Lead Inner and Outer Saddles until they are flush, using 5 mil adhesive backed Kapton or equivalent and G-11CR Non-Lead End Saddle Shim Stock (MD-369816 (Inner) & MD-369817 (Outer)) or equivalent.

J Howell
Technician(s)

11/21/01
Date

4.4 Install the Non-Lead End Full Preload Plate (MB-369061) as per (ME-369655).

J Howell
Technician(s)

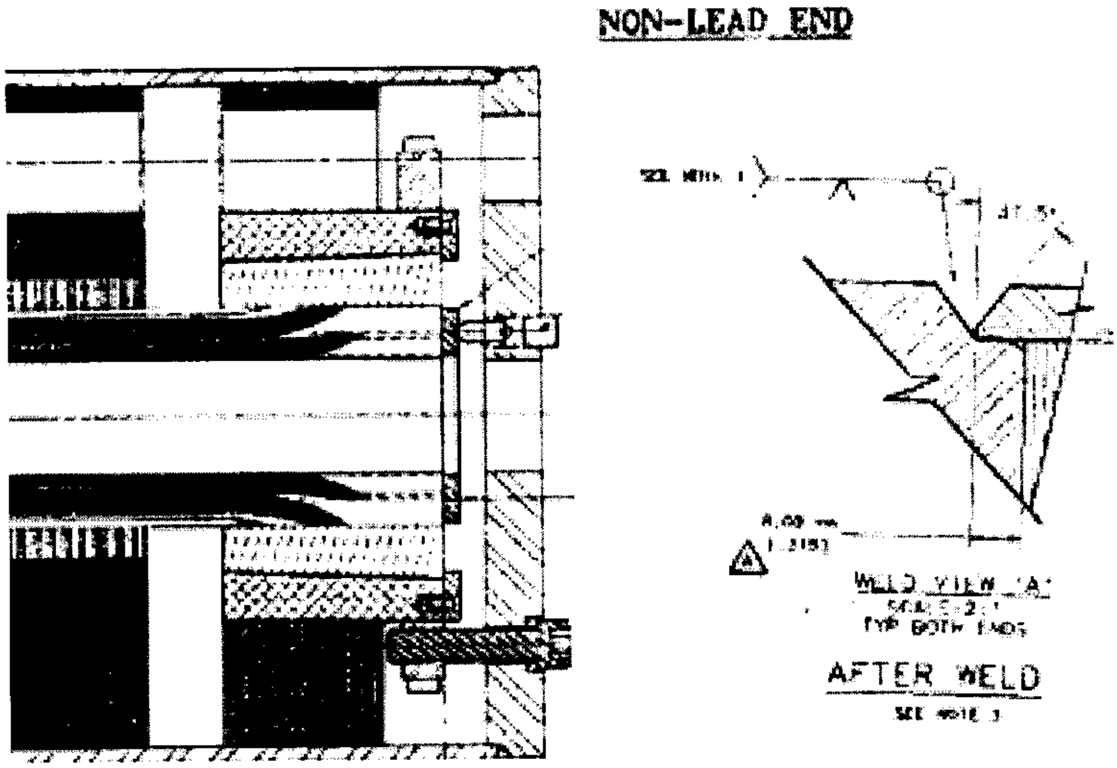
11/21/01
Date

5.0 End Plate Installation

5.1 Clean the Non-lead End Plate area with Isopropyl Alcohol (Fermi stock 1920-0300) Kimwipes (Fermi stock 1660-2500) or equivalent, and a vacuum to remove all dirt and foreign materials.

Technician ______ Date 11-19-01

5.2 Install the Non-Lead End – End Plate (ME-369750) as per (ME-369655).



Quadrant 1 is UP.

Note(s):

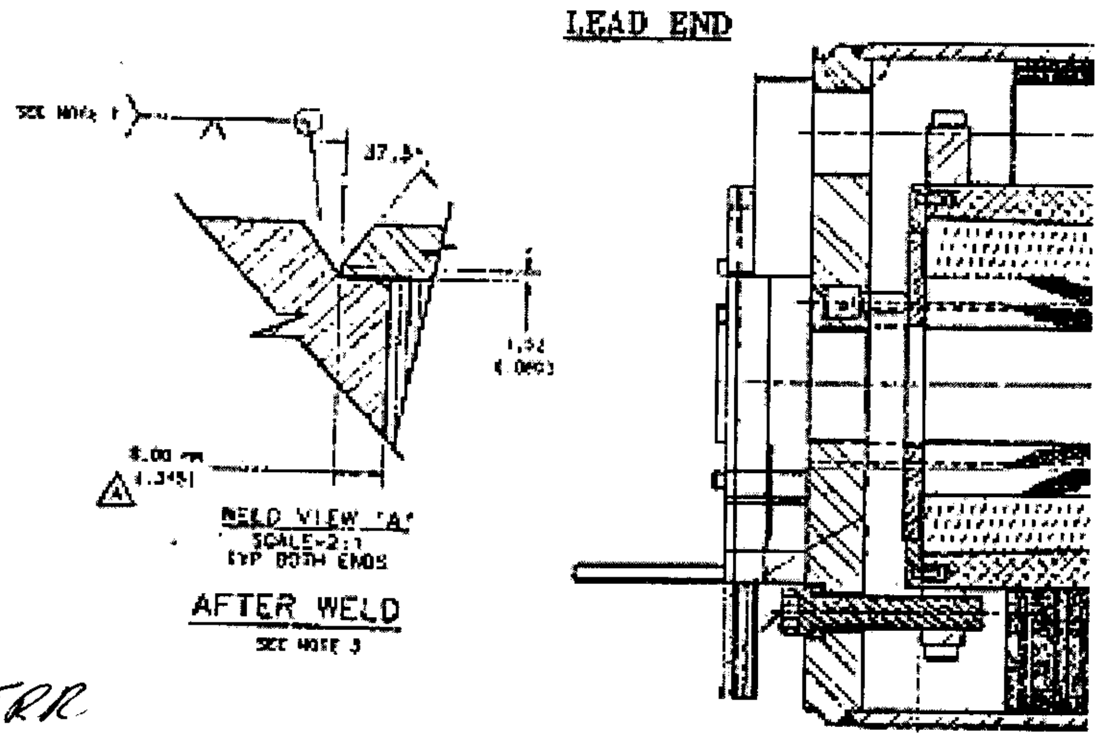
The End Plate should be facing outward so the stamped or marked area with the nomenclature, part number, and "Top" is visible.
Check the Tapped holes prior to installation for damage.

Technician ______ Date 11-19-01

5.3 Clean the Lead End Plate Area with Isopropyl Alcohol (Fermi stock 1920-0300), Kimwipes (Fermi stock 1660-2500) or equivalent and vacuum to remove all dirt and foreign materials.

Technician(s) ______ Date 11-27-01

5.4 Install the Lead End – End Plate (ME-369749) as per (ME-369655). While installing, pull out the Instrumentation and Power Lead Wires through the proper openings as per the figure below.



TRR

Quadrant 1 is UP.

Note(s):

The End Plate should be facing outward so the stamped or marked area with the nomenclature, part number, and "top" is visible.
Check the Tapped holes prior to installation for damage.

Technician(s) ______ Date 11-27-01

5.5 Record the Length from the Outer Edge of the Lead End Plate to the Outer Edge of the Non-lead End Plate before welding.

All Quadrant lengths must be with in .030" of each other.

Position of the Measurement	Measurement in Inches (For Reference Only)
Q1	225.773
Q2	225.765
Q3	225.780
Q4	225.758

Technician(s) 11-27-01
Date

X 5.6 Verify that the End Plates are properly installed as per the Final Coldmass Assembly (ME-369655).

Production Engineer/Designee 11-27-01
Date

5.7 While the Non-Lead End Plate is in position as per the Final Cold Mass Assembly (ME-369655), weld the Non-Lead End – End Plate to the Cold Mass Skin as per (ME-369655).

Weldor 11/28/01
Date

5.8 Clean the Weld area with a Stainless Steel Wire Brush (Fermi stock 1246-0860), Isopropyl Alcohol (Fermi stock 1920-0300), Kimwipes (Fermi stock 1660-2500) or equivalent and vacuum.

Technician(s) 11-28-01
Date

5.9 While the Lead End Plate is in position as per the Final Cold Mass Assembly (ME-369655). Weld the Lead End –End Plate to the Cold Mass Skin as per (ME-369655).

Weldor 11/28/01
Date

5.10 Clean the Weld with a Stainless Steel Wire Brush (Fermi stock 1246-0860), Vacuum, Isopropyl Alcohol (Fermi stock 1920-0300) and Kimwipes (Fermi stock 1660-2500) or equivalent.

D Murczyk
Technician(s)

11-28-01
Date

5.11 Record the Length from the Outer Edge of the Lead End Plate to the Outer Edge of the Non-lead End Plate after welding.

Note(s):

The measurement should be within 1/8" of the readings taken in step 5.5.

Position of the Measurement	Measurement in Inches	Nominal
Q1	225. 5/8	225.926"
Q2	225 9/16	225.926"
Q3	225. 9/16	225.926"
Q4	225 5/8	225.926"

D Murczyk
Technician(s)

11-29-01
Date

6.0 Bolt and Bullet Installation

6.1 Apply Areolex (open Purchase - Chemical Research Co.) to all threaded parts being installed onto the End Plates except the bolts. Apply anti-seize to the Axial Preload Bolts (MB-369267)

Technician / J Gould   Date 11/30/01

6.2 Assemble the Bullet Assemblies (MD-~~369293~~ 363731) for the Lead and Non-Lead End.

Technician / J Gould   Date 11/30/01

6.3 Install the Bullet Pusher Screws (MB-344583) and the Bullet Load Slugs (MB-344584) in (4) places on the Lead End and (4) places on the NON-Lead End as per (ES-369871). Be careful not to damage the wires or the solder connections.

Note(s):

Before the final torque is applied the Production Engineer and/or Magnet Physicist are to be present.

Technician J Gould   Date 11/30/01

X 6.4 Verify the stabilization of the Torque applied to the Bullet Pusher Screws. If no anomalies occurred during this process, state "no anomalies", else comment below.

Comment:

Need TRR. I witnessed the torque on the axial preload bolts (both ends) no anomalies. Not possible to take bullett readings → no longer instrumented.

Responsible Authority/Physicist   Date 11-30-01

TRRS' NEEDED:

6.1 - REMOVE ANTI-SEIZE FROM STEP

6.2 - CHANGE BULLET ASSY #

6.3 - REFERENCE TORQUE SPEC
- ADD SIGN FOR PRO. ENG OR PHYS AT TORQUE STEP.

7.0 Electrical Inspection

7.1 Perform an electrical inspection on each of the individual Inner Coils, Outer Coils, Quadrants and the Magnet. Refer to the Valhalla and Leader Free Standing Coil Measurement Procedure (ES-292306), and the Procedure for Electrical Inspection of Voltage Taps (ES-301383).

Note(s):

Ensure that all measurements are recorded correctly, and have the proper value and symbol (i.e., mΩ, mH, etc.).

Valhalla 4300B settings:

Test current	________	Off (not testing)
Power	________	On
Full scale voltage	________	20 mV
Amp selector knob	________	1 A
Temperature compensator	________	On
Test current	________	On (testing)

Hp 4284:

Function	________	"Ls-Q" selected

Record the Serial Number of the test equipment used.

Valhalla 32-858

HP 4284 2848J00912

Resistance		Inner	Outer	Total	Pass	Fail
Nominal		345 mΩ to 390 mΩ	410 mΩ to 455 mΩ	560 to 585 mΩ		
Quadrant 1	**Inner**	.2578 mΩ				
	Outer		.3157 mΩ			
	Total			.572~~[illegible]~~ mΩ		
Quadrant 2	**Inner**	.2548 mΩ				
	Outer		.3203 mΩ			
	Total			.5759 mΩ		
Quadrant 3	**Inner**	.2575 mΩ				
	Outer		.3202 mΩ			
	Total			.5756 mΩ		
Quadrant 4	**Inner**	.2586 mΩ				
	Outer		.3199 mΩ			
	Total			.5769 mΩ		

Inductance		Inner	Outer	Total	Pass	Fail
Nominal		620-650 μH	1.120 to 1.17 mH	2.880 to 2.935 mH		
Quadrant 1	**Inner**	523.361 μH				
	Outer		855,837 μH ~~mH~~			
	Total			2.29353 ~~1.326~~ mH		
Quadrant 2	**Inner**	521.097 μH				
	Outer		851.318 mH			
	Total			2,28703 mH		
Quadrant 3	**Inner**	520,867 μH				
	Outer		850.295 mH			
	Total			2.28804 mH		
Quadrant 4	**Inner**	5.24,560 μH				
	Outer		854,183 mH			
	Total			2,29593 mH		

Q-Factor		Inner	Outer	Total	Pass	Fail
Nominal		3.0 to 3.5	4.3 to 5.0	4.5 to 5.2		
Quadrant 1	**Inner**	2.95				
	Outer		2.79			
	Total			4.68		
Quadrant 2	**Inner**	2.94				
	Outer		2.79			
	Total			4,69		
Quadrant 3	**Inner**	2.93				
	Outer		2.77			
	Total			4,65		
Quadrant 4	**Inner**	2.92				
	Outer		2,76			
	Total			4.63		

Inspector

12-3-01
Date

	Nominal	Measurements
Resistance	2.3 Ω	2.327 Ω
Q@ 1 kHz	4.3	4.99
Inductance (Ls) @ 1 kHz	17 mH	13.4924 mH

Inspector: Don Muczyn Date: 12-3-01

LIMIT NEEDS TO BE SWITCHED + LABELS

TRR #1293

Resistance Test	Limit	Actual Measurement	Pass	Fail
Heater Strips 1/2	9.10 to 9.50 Ω	19.858 B- Ω		
Heater Strips 2/3	9.10 to 9.50 Ω	19.844 A- Ω		
Heater Strips 3/4	9.10 to 9.50 Ω	19.858 B+ Ω		
Heater Strips 4/1	9.10 to 9.50 Ω	19.844 A+ Ω		

Inspector: [signature] Date: 12/3/01

7.2 Verify torque on Pre-Load Bolts as per (ES-369871).

Technician(s): D Muczyn Date: 12-3-01

8.0 Make Quadrant Splices

DR # 0284

NOT UNTIL AFTER SOLDERING IS DONE

TRR 369875

8.1 Attach the Coil Splice Block #1 (MD-344908), the Coil Splice Block #2 (MD-344909), the Coil Splice Block #3(MD-344910) and the Coil Splice Block #4 (MD-344911) to the Lead End Plate (ME-369572) as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) SHowld Date 12/4/01

8.2 MOVE TO AFTER 8.8 Attach all three Support Block - Bases (MB344942) and the Coil Support Block (MA-369215) to the Lead End Plate (ME-369572) as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) SHowld Date 12-4-01

8.3 Form Power Leads into slots in Coil Splice Blocks as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) SHowld / D Murphy Date 12-5-01

8.4 Attach the Coil Splice - Intermediate Block #1 (MD-344919), both the Coil Splice - Intermediate Block #2, #3 (MD-344920) and the Coil Splice - Intermediate Block #4A (MD-344921) to the Coil Splice Blocks as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) SHowld / D Murphy Date 12-5-01

8.5 Form Power Leads into slots in Coil Splice - Intermediate Blocks as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) SHowld / D Murphy Date 12-5-01

8.6 Attach the Coil Splice - Intermediate Block #4B (MD-369844) to the Coil Splice - Intermediate Block #4A as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) SHowld / D Murphy Date 12-5-01

8.7 Form Power Leads into slots in Coil Splice - Intermediate Blocks as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) ________ Date 12/5/01

8.8 Attach all four Support Block Covers to the Coil Splice - Intermediate Blocks as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) ________ Date 12-5-01

DR# 0286

SOLDERING IS DONE HERE! TRR NEEDED

8.9 Attach all three Support Block - Tops (MB-344795) to the Support Block - Base (MB-344942) and all three Fillers (MB-369214) as per Quadrant Splice Assembly (MD-344925).

Technician(s) ________ Date 12-5-01

8.10 Attach (2) Voltage Taps to each Quadrant Splice and (2) Voltage Taps to each Power Lead.

TRR HOW LONG? LOCATION?

Locations	Wire Type (MA-369832)	Completed
Power Leads Q4I	**26 Gauge**	✓
	26 Gauge	✓
Power Leads Q3I	**26 Gauge**	✓
	26 Gauge	✓
QS A Q2O / Q1O (1/2 Coil Tap)	**26 Gauge**	✓
	26 Gauge	✓
QS B Q3O / Q1I (1/4 Coil Tap)	**26 Gauge**	✓
QS C Q4O / Q2I (1/4 Coil Tap)	**26 Gauge**	✓

Technician(s) ________ Date 12-5-01

8.11 Install Springboard Assembly (MC-369842 & MC-369843) onto the Cold Mass Assembly. Wrap the Springboard Assemblies in Kapton.

Technician(s) ________ Date 12-10-01

9.0 Lead End Electrical Installations

9.1 Perform an electrical inspection on each of the individual Inner Coils, Outer Coils, Quadrants and the Magnet. Refer to the Valhalla and Leader Free Standing Coil Measurement Procedure (ES-292306), and the Procedure for Electrical Inspection of Voltage Taps (ES-301383).

Note(s):

Ensure that all measurements are recorded correctly, and have the proper value and symbol (i.e., mΩ, mH, etc.).

Valhalla 4300B settings:

Test current	________	Off (not testing)
Power	________	On
Full scale voltage	________	20 mV
Amp selector knob	________	1 A
Temperature compensator	________	On
Test current	________	On (testing)

Hp 4284:

Function	________	"Ls-Q" selected

Record the Serial Number of the test equipment used.

Valhalla 32856

HP 4284 2848J00912

Resistance		Inner	Outer	Total	Pass	Fail
Nominal		345 mΩ to 390 mΩ	410 mΩ to 455 mΩ	560 to 585 mΩ		
Quadrant 1	Inner	~~.3218~~ gpm mΩ	.2602			
	Outer		3218 mΩ			
	Total			.5822 mΩ		
Quadrant 2	Inner	.2595 mΩ				
	Outer		.3232 mΩ			
	Total			.5829 mΩ		
Quadrant 3	Inner	.2574 mΩ				
	Outer		.3225 mΩ			
	Total			.5789 mΩ		
Quadrant 4	Inner	.2590 mΩ				
	Outer		.3240 mΩ			
	Total			.5823 mΩ		

Inductance		Inner	Outer	Total	Pass	Fail
Nominal		620-650 μH	1.120 to 1.17 mH	2.880 to 2.935 mH		
Quadrant 1	Inner	525.916 μH				
	Outer		863.616 mH			
	Total			2.326 mH		
Quadrant 2	Inner	524.676 μH				
	Outer		860.567 mH			
	Total			2.31643 mH		
Quadrant 3	Inner	520.477 μH				
	Outer		850.712 mH			
	Total			2.29084 mH		
Quadrant 4	Inner	523.275 μH				
	Outer		854.983 mH			
	Total			2.29845 mH		

Q-Factor		Inner	Outer	Total	Pass	Fail
Nominal		3.0 to 3.5	4.3 to 5.0	4.5 to 5.2		
Quadrant 1	Inner	2.92				
	Outer		2.76			
	Total			4.60		
Quadrant 2	Inner	2.92				
	Outer		~~2.92~~ 2.77 dm			
	Total			4.61		
Quadrant 3	Inner	2.92				
	Outer		2.76			
	Total			4.63		
Quadrant 4	Inner	2.91				
	Outer		2.74			
	Total			4.61		

D Murphy
Inspector

12-5-01
Date

	Nominal	Measurements
Resistance	2.3 Ω	2.293 Ω
Q@ 1 kHz	4.3	4.99
Inductance (Ls) @ 1 kHz	17 mH	13.482 mH

[signature]
Inspector

12/5/01
Date

B- & B+
~~A & B~~
A- & A+

Resistance Test	Limit	Actual Measurement	Pass	Fail
Heater Strips 1/2	9.10 to 9.50 Ω	19.88 Ω		
Heater Strips 2/3	9.10 to 9.50 Ω	19.88 Ω		
Heater Strips 3/4	9.10 to 9.50 Ω	NA Ω		
Heater Strips 4/1	9.10 to 9.50 Ω	NA Ω		

DR No. HGQ-0270

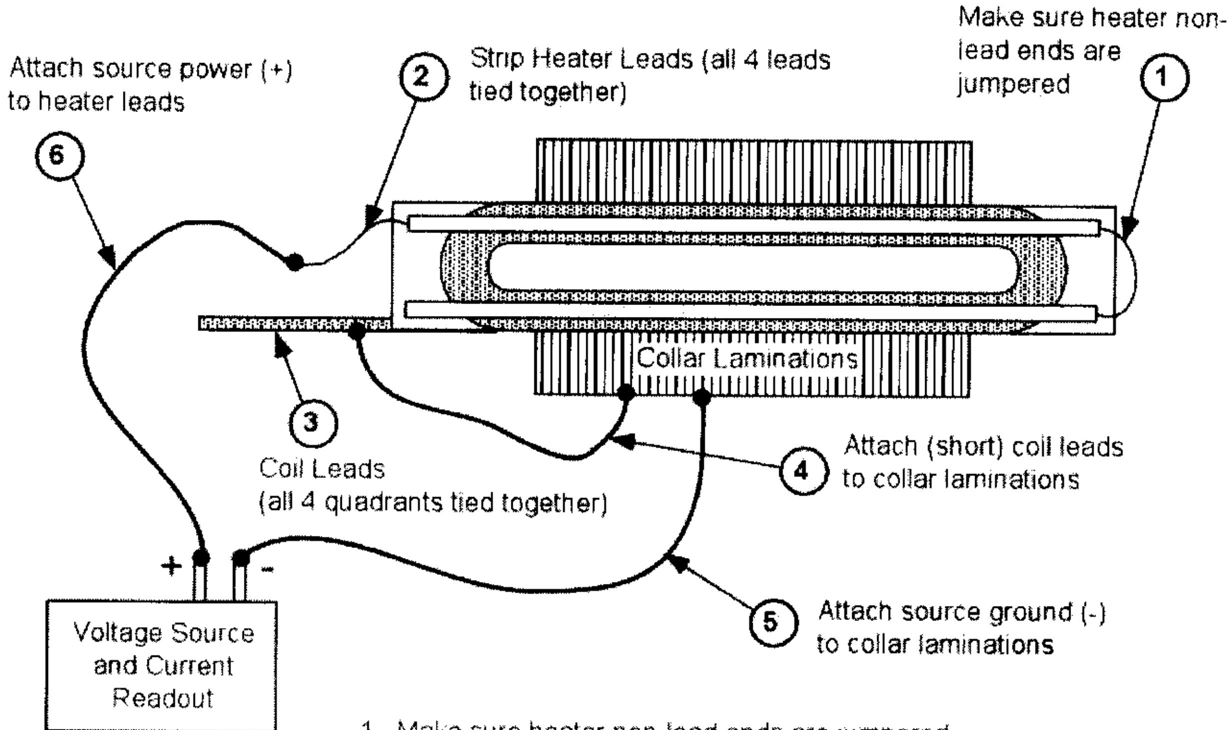
D Murphy
Inspector

12-5-01
Date

DR No. HGQ-0290

X.9.2 Perform a Hipot on the Collared Coil Assembly (**Maximum Leakage 3μA**)

1st Hipot - Heaters to both Coil and Ground



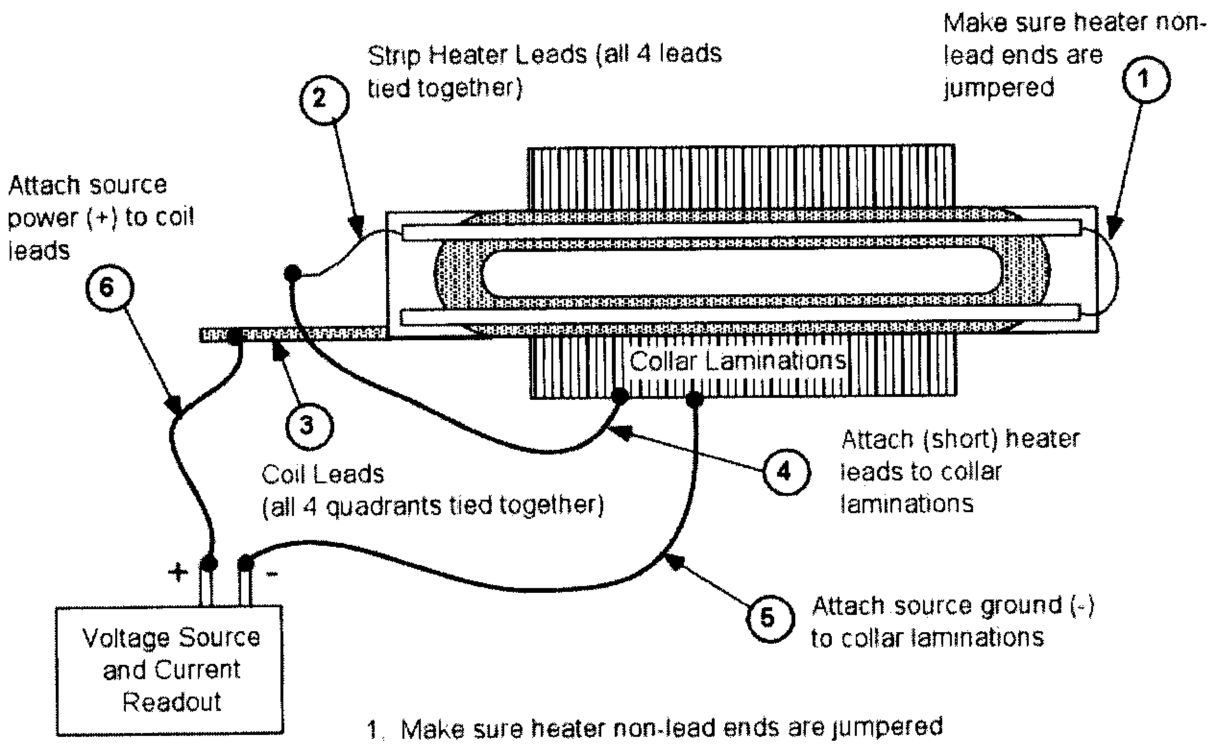
1. Make sure heater non-lead ends are jumpered.
2. Tie all 4 heater leads together
3. Tie all 4 coil quadrants together
4. Attach (short) coil leads to collar laminations
5. Attach source ground (-) to collar laminations
6. Attach source power (+) to heater leads
7. Increase voltage to 5kv or until leakage exceeds 3uA. Voltage not in any circumstances to exceed 5kv.

5 KV	Measurement(s)
Heaters to Ground (Coils Grounded)	~~3~~ SWG .4

[signature]
Inspector

1/17/02
Date

2nd Hipot - Coil to Ground Hipot



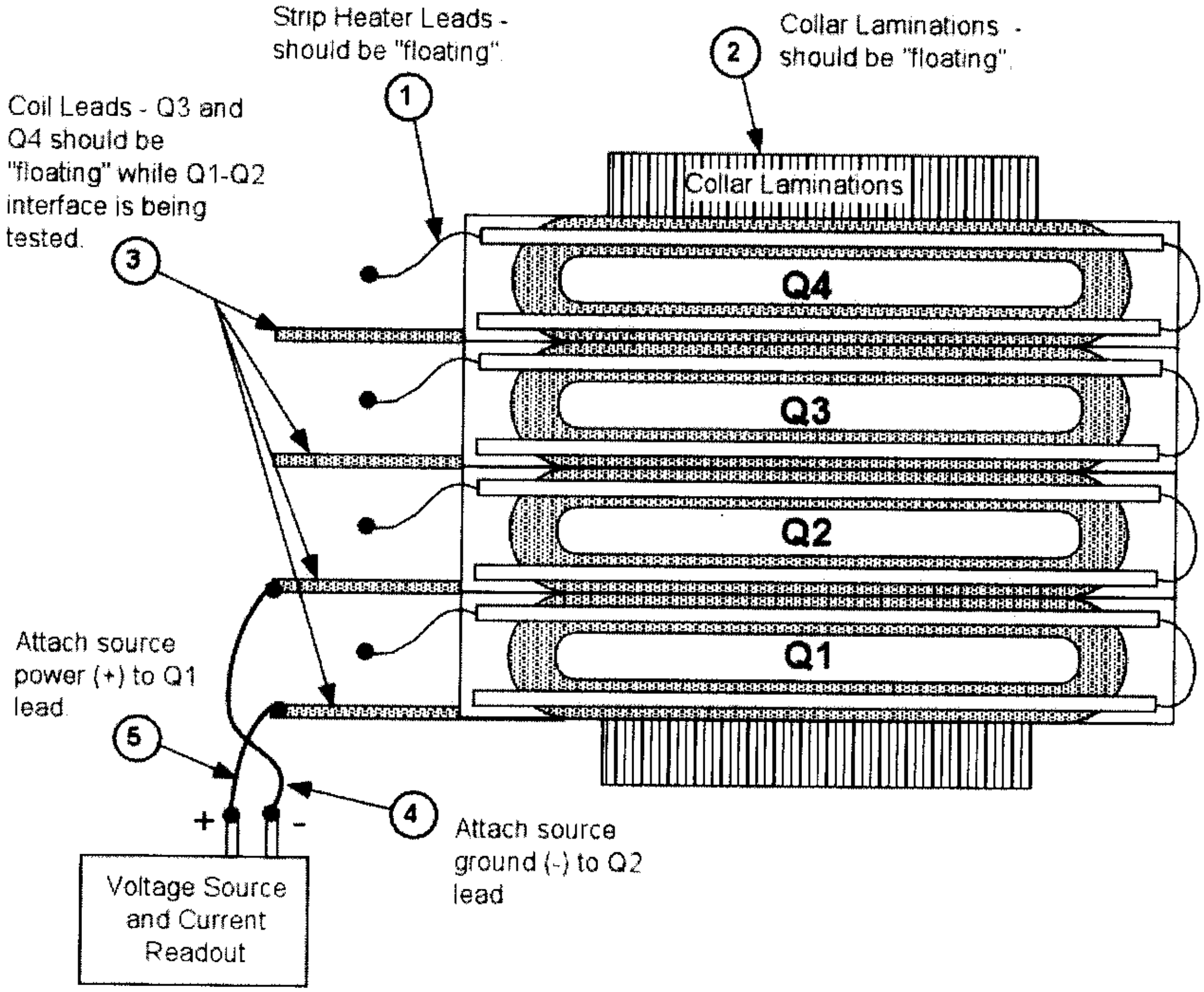
1. Make sure heater non-lead ends are jumpered
2. Tie all 4 heater leads together
3. Tie all 4 coil quadrants together
4. Attach (short) heater leads to collar laminations
5. Attach source ground (-) to collar laminations
6. Attach source power (+) to coil leads
7. Increase voltage to 5kv or until leakage exceeds 3uA. Voltage not in any circumstances to exceed 5kv.

5 KV	Measurement(s)
Coils to Ground (Heaters Grounded)	.2

Inspector ____________ Date 1/17/02

3rd Hipot - Quadrant-to-Quadrant Hipot

(4 quadrants shown "developed")



1. Make sure all heaters are "floating" (electrically isolated)
2. Make sure all collar laminations are "floating" (electrically isolated)
3. Make sure all leads from Q3 and Q4 coils are "floating" (electrically isolated).
4. Attach source ground (-) to Q2 lead (either inner or outer coil).
   Other end (either inner or outer coil) must be electrically isolated.
5. Attach source power (+) to Q1 lead (either inner or outer coil)
   Other end (either inner or outer coil) must be electrically isolated.
6. Increase voltage to 3kv or until leakage exceeds 3uA. Voltage under any circumstances not to exceed 3kv
7. Repeat steps 3-6 for Q2-Q3 leads.
8. Repeat steps 3-6 for Q3-Q4 leads.
9. Repeat steps 3-6 for Q4-Q1 leads

11-27-02

MQXB01

Prog. #[redacted]12 5000 V., 3 V/S, 5 uA Max, Ramp 100 uA	
Heaters to ground w/ coils grounded:	150 nA
Coils to ground w/ heaters grounded:	248 nA

Coil to Coil @ 3.0 KV	Measurement(s)
Quadrant 1 to Quadrant 2	
Quadrant 2 to Quadrant 3	
Quadrant 3 to Quadrant 4	
Quadrant 4 to Quadrant 1	

N/A
Inspector ______________________ Date ______________________

STOP

9.3 Verify that the results in Step 9.0 are acceptable.
Approved for next Assembly Procedure.

Responsible Authority/Physicist ______________________ Date 1-17-02

9.4 Perform Mole Measurement per (ES-344801).

Technician(s) ______________________ Date 2-27-02

10.0 Cold Mass Straightness Measurement

10.1 Move the completed Cold Mass assembly to rollers on the granite table. The rollers should be placed 124" apart, center to center, on the table

A Gould
Technician(s)

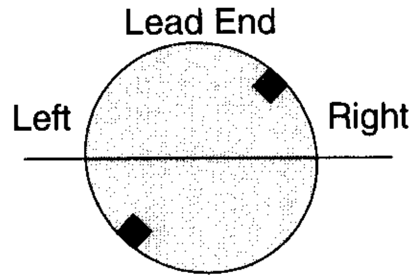
4/5/02
Date

10.2 Roll the Cold Mass such that the Yoke/Skin Weld Key is at approximately 45°.

A Gould
Technician(s)

4/8/02
Date

10.3 Stretch a wire from End Plate to End Plate in the horizontal plane. Measure the distance between the Wire and the Skin every 1' along the length.

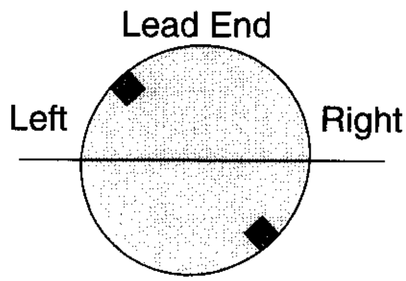


Location on Cold Mass	Left	Right
Lead End Plate	0	0
1'	0	0
2'	0	0
3'	0	.004
4'	0	.004
5'	0	.005
6'	0	.004
7'	0	.006
8'	0	.005
9'	0	.005
10'	0	.004
11'	.001	0
12'	.001	0
13'	0	0
14'	0	0
15'	0	0
16'	0	0
17'	0	0
18'	0	0
Return End Plate	0	0

[signature]
Technician(s)

4/8/02
Date

10.4 Roll the Cold Mass 90°. Stretch a wire from End Plate to End Plate in the horizontal plane. Measure the distance between the Wire and the Skin every 1' along the length.



Location on Cold Mass	Left	Right
Lead End Plate	0	0
1'	0	.001
2'	0	SWG ~~.004~~ 0
3'	0	0
4'	0	.004
5'	0	.002
6'	0	.002
7'	0	.003
8'	0	.004
9'	0	.006
10'	0	.006
11'	0	.004
12'	0	.005
13'	0	.005
14'	0	.003
15'	0	.003
16'	0	SWG ~~.003~~ 0
17'	0	0
18'	0	0
Return End Plate	0	0

S. Gould
Technician(s)

4/8/02
Date

10.5 Roll the Cold Mass back to the orientation such that the leads exit the lead block at the bottom of the assembly.

S Howell
Technician(s)

4/8/02
Date

11.0 Cold Mass Lug Attachment Point Determination

11.1 Review the Cold Mass Mechanical Twist measurements taken in Step 9.3 of the LHC Yoke & Skinning Assembly Traveler (5520-TR-333497).
Determine the position of the Average Magnetic Field Axis from a plot of the Mechanical Twist Measurements. Attach the Twist Plot and record the distance from the Magnet Lead End.

Distance from Magnet Lead End 150"

T. Page
Responsible Authority/Physicist

4/8/02
Date

11.2 Mark the distance from the Magnet Lead End, as recorded above, on the Cold Mass Skin on both sides with a marker.

A Howld
Technician(s)

4/8/02
Date

11.3 Place the Mechanical 'Twist' Measurement fixture on the Cold Mass at the marked location.

A Howld
Technician(s)

4/8/02
Date

11.4 Place and secure an Angle Block on the Twist Measurement Fixture such that there is a level surface to place the precision level on.

A Howld
Technician(s)

4/8/02
Date

11.5 Rotate the Cold Mass, as needed, to zero out the Bench Level (Moro 150mm #031534 or equivalent).

A Howld
Technician(s)

4/8/02
Date

X 11.6 Verify that the Cold Mass was properly rotated.

T. Rice
Lead Person

4-8-02
Date

11.7 Using Machinist's Blue Ink, blue the area around where the lug will be placed, on both sides of the Cold Mass, and color the location of the reference center of the Cold Mass as per Cold Mass Welded Assembly (ME-390309).

Technician(s) AGould   Date 4/9/02

11.9 Using a Height Gauge, scribe Centerlines on both sides of the Cold Mass at the approximate location that the Cold Mass Support Lug will be placed.

Technician(s) AGould   Date 4/9/02

11.10 Measure from the Lead End to determine the location of the reference center.

Location of Magnetic Center 113.263" GRK

Technician(s) AGould   Date 4/9/02

11.11 Measure from the Reference Center and scribe the location of the edges of the lug that will be placed on the Cold Mass as per Cold Mass Welded Assembly (ME-390309).

Technician(s) AGould   Date 4/9/02

11.12 Using a piece of Mylar, wrap the Cold Mass at the position of the lugs. Mark the location of the scribed centerlines and the notch in the Yoke/Skin Alignment Key.

Technician(s) AGould   Date 4/9/02

11.13 Unroll the Mylar and measure the distances between the marks to confirm the scribe marks are placed 180° apart on the Cold Mass, and are accurate with respect to the key.

Technician(s) AGould   Date 4/9/02

12.0 Production Complete

12.1 Process Engineering verify that the Large Hadron Collider Cold Mass and Final Assembly Traveler (5520-TR-333498) is accurate and complete. This shall include a review of all steps to ensure that all operations have been completed and signed off. Ensure that all Discrepancy Reports, Nonconformance Reports, Repair/Rework Forms, Deviation Index and dispositions have been reviewed by the Responsible Authority for conformance before being approved.

Comments:

Bob [signature] 7/26/02

Process Engineering/Designee Date

ORIGINAL

TD/ENGINEERING & FABRICATION

PARTS KIT REQUEST

IMPORTANT NOTES:
1) MAGNET NUMBER MUST BE FILLED IN.
2) ONLY ONE FORM PER MAGNET.
3) PARTS COORDINATOR OR DESIGNEE MUST SIGN THIS FORM.
4) MATERIAL CONTROL WILL ISSUE PARTS AND RECORD ROUTING NUMBER.
5) ANY QUANTITIES NOT AVAILABLE WILL HAVE COMMENTS RETURNED TO THE PARTS COORDINATOR FOR REVIEW.

RELEASED BY

MAGNET NUMBER: MQXB[redacted] 01

PRODUCTION SIGNATURE: T J Gardner

TODAYS DATE: 15-Jun-01

NEED DATE: 20-Jun-01

DELIVER TO ICB

BUDGET CODE: LQC

ISSUE VERIFICATION

MATERIAL CONTROL SIGNATURE: [signature]

DATE ISSUED TO STOCKROOM: 6/15/01

THIS KIT LIST IS FOR: ME-369578 | A | FINAL COLD MASS ASSEMBLY

PART NUMBER	REV	DESCRIPTION	REQUIRED QTY/ASS'Y		MATERIAL: QTY FILLED OUT BY STOCK ROOM — ISSUED	ROUTE FORM	NOT AVAIL	CONTROL: FILLED OUT BY EXPEDITER — DATE AVAIL	COMMENTS TO PRODUCTION MANAGER	PROD VERIFY PART	SUPT. VERIFY PART
344583	A	BULLET PUSHER SCREW	8	EA	8	74220		6/15/01			
344795	A	QUADRANT SPLICE TOP SUPPORT BLOCK	3	EA	3	74293					
~~344825~~	~~G1~~	~~WIRE FEED THRU TUBE 80" LONG~~	~~2~~	~~EA~~	~~2~~	~~67756~~	TJG				
344908	A	COIL SPLICE BLOCK #1	1	EA	1	74537					
344909	B	COIL SPLICE BLOCK #2	1	EA	1	74538					
344910	B	COIL SPLICE BLOCK #3	1	EA	1	74525					
344911	B	COIL SPLICE BLOCK #4	1	EA	1	74524					
344919	A	INTERMEDIATE SPLICE BLOCK #1	1	EA	1	69293					
344920	A	INTERMEDIATE SPLICE BLOCK #2 & #3	2	EA	2	69294					
344921	A	INTERMEDIATE SPLICE BLOCK #4 PART A	1	EA	1	74541					
344922	A	INTERMEDIATE SPLICE BLOCK #4 PART B	1	EA	1	74539					
344923	A	SUPPORT BLOCK COVER	4	EA	4	69297					
344942	B	QUADRANT SPLICE BOTTOM SUPPORT BLOCK	3	EA	3	74343					
369060	C	LE FULL PRELOAD PLATE	1	EA	1	74803					
369061	A	RE FULL PRELOAD PLATE	1	EA	1	74791					
369214	A	FILLER, G-11 CR	3	EA	3	74560					
369215	A	COIL SUPPORT BLOCK	1	EA	1	74558					
369265	A	SHCS 3/4-10x4 ss	4	EA	4	69533					
369274	A	SOCKET HEAD CAP SCREW 10-32 X 1-1/4"	6	EA	6	72764					
369276	A	FLAT HEAD CAP SCREW #10-32 X 1-1/2"	28	EA	28	72770					
369277	A	SOCKET HEAD CAP SCREW 1/4-20 X 3/4"	6	EA	6	69837					
369278	A	SOCKET HEAD CAP SCREW #10-24 X 1-1/4"	8	EA	8	69982					

RETURN THIS COMPLETED PARTS KIT REQUEST WITH THE ISSUED PARTS TO THE PARTS COORDINATOR.

Doug Kelley 12304 06-21-01 : STOCKROOM SIGNATURE AND DATE

TRAVELER NO. TR-333498

KIT IS COMPLETE (PARTS COORDINATOR SIGNATURE): [signature] BADGE # 4529

DATE 21 JUN 01

Revision Request Control Number: 1293

Specification Number: 5520 - TR - 333498 Current Revision: A

Traveler or Document Title: LHC Final Cold Mass Assembly Traveler

Step #/Description of Revision:

3.1 Deleted Step. Step performed in "Yoke & Skinning Traveler", Step 9.1.
3.2 Modified Step. Included labeling of Power Wires as per Figure 1. DR No. HGQ-0273.
7.1 Modified Step. Revised Resistance Test Table per figure 2 in Step 3.2. Updated nominals. R=2.305 W, Q=5.036, Ls=13.3376 mH.
9.1 Modified Step. Revised Resistance Test Table per figure 2 in Step 3.2. Updated nominals. R=2.305 W, Q=5.036, Ls=13.3376 mH.

Jim Rife	Jim Rife	1/9/2002
Originator	Responsible Authority	Date

Revision Incorporated into the Traveler: John Szostak — Revision Incorporated By; Date: 3/20/02

Process Engineering Final Review: [signature] — Process Engineering Designee; Date: 3/20/02

Instructions for the completion of the Revision Request Form

Note(s):

Multiple steps may be effected by one Revision Request Form but only one specific Traveler or Document may be effected by each Revision Request Form.

If completing this form by hand, a Revision Request Control Number must be obtained before processing.

If completing this form entirely by electronic means, the printed copy to be filed in the Process Engineering Office is to be initialed by the individual incorporating the Revision Request and the individual who reviewed the Traveler or Document.

Originator Instructions:

1) Specification Number: - Enter the Specification Number of the Traveler or Document to be revised. (Document title is inserted automatically from the spec. #)

2) Current Revision: - Enter the Revision of the Traveler or Document to be revised.

3) Step# / Description of the Revision: - Enter a description of the revision to be made and the step# it applies to, if applicable. If needed to describe the revision attach a copy of the page(s). If the revision is coming from a related document such as a Discrepancy Report or an Engineering Order attach a copy of that document to the Revision Request Form.

4) Originator: - Originator is the person generating the form. (Select Name from List)

5) Responsible Authority: - Responsible Authority is person responsible for the process in question. (Select Name from List)

Process Engineering Office Instructions:

1) Revision Incorporated into the Traveler: - Signature of the individual who incorporated the revision.

2) Process Engineering Final Review: - Review the Traveler or Document revised, sign and date the form. The original completed Revision Request Form will be retained by the Process Engineering Office in the Revision Request Binder.

Revision Request Control Number: 1318

Specification Number: 5520 - TR - 333498 Current Revision: A

Traveler or Document Title: LHC Final Cold Mass Assembly Traveler

Step #/Description of Revision:

6.2 Modified Step. Changed MD-369293 to MD-369731. DR No. HGQ-0281.
8.2 Modified Step. Changed Part Number (MB-344942) to (MB-369875).DR No. HGQ-0284.
8.2 Moved Step. Moved to after Step 8.8. (Becomes New Step 8.8)
8.3 Modified Step. Added "...add all three Filler Pieces (MB-369214) and modify as needed...".
8.9 Modified Step. Changed Part Number (MB-344942) to (MB-369875).DR No. HGQ-0284.
8.10 Deleted Step. No Voltage Taps.
8.10 Modified Step (New Step 8.10) Changed last sentence to "Wrap the Springboard Assemblies in Kapton and then wrap with Kevlar String(MA-369912) every ½ - ¾" over Kapton." DR No. HGQ-0288.

Donald Nurczyk	Jim Rife	1/2/2002
Originator	Responsible Authority	Date

Revision Incorporated into the Traveler:

John J. [signature]	3/20/02
Revision Incorporated By	Date

Process Engineering Final Review:

[signature]	3/20/02
Process Engineering/Designee	Date

Instructions for the completion of the Revision Request Form

Note(s):

Multiple steps may be effected by one Revision Request Form but only one specific Traveler or Document may be effected by each Revision Request Form.

If completing this form by hand, a Revision Request Control Number must be obtained before processing.

If completing this form entirely by electronic means, the printed copy to be filed in the Process Engineering Office is to be initialed by the individual incorporating the Revision Request and the individual who reviewed the Traveler or Document.

Originator Instructions:

1) Specification Number: - Enter the Specification Number of the Traveler or Document to be revised. (Document title is inserted automatically from the spec. #)

2) Current Revision: - Enter the Revision of the Traveler or Document to be revised.

3) Step# / Description of the Revision: - Enter a description of the revision to be made and the step# it applies to, if applicable. If needed to describe the revision attach a copy of the page(s). If the revision is coming from a related document such as a Discrepancy Report or an Engineering Order attach a copy of that document to the Revision Request Form.

4) Originator: - Originator is the person generating the form. (Select Name from List)

5) Responsible Authority: - Responsible Authority is person responsible for the process in question. (Select Name from List)

Process Engineering Office Instructions:

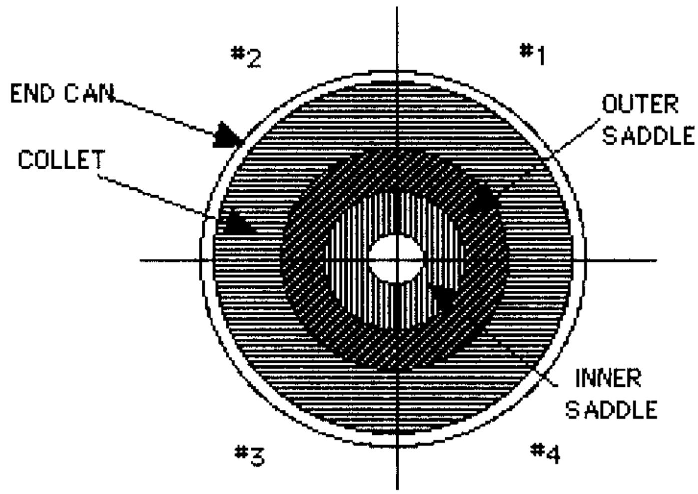
1) Revision Incorporated into the Traveler: - Signature of the individual who incorporated the revision.

2) Process Engineering Final Review: - Review the Traveler or Document revised, sign and date the form. The original completed Revision Request Form will be retained by the Process Engineering Office in the Revision Request Binder.

4.0 Bullet Pressure Plate Installation

4.1 Shim the Lead End Inner and Outer Saddles until they are flush, using 5 mil adhesive backed Kapton or equivalent and G-11CR Lead End Saddle Shim Stock (MD-369818 (Inner) & MD-369819 (Outer)) or equivalent.

Technician(s) DMurcyff   Date 11-21-01



VIEW FROM LEAD END
LOOKING TOWARD RETURN END

4.2 Install the Lead End Full Preload Plate (MB-369060).

Technician(s) DMurcyff   Date 1-3-02

4.3 Shim the Non-Lead Inner and Outer Saddles until they are flush, using 5 mil adhesive backed Kapton or equivalent and G-11CR Non-Lead End Saddle Shim Stock (MD-369816 (Inner) & MD-369817 (Outer)) or equivalent.

Technician(s) N/A   Date

4.4 Install the Non-Lead End Full Preload Plate (MB-369061) as per (ME-369655).

Technician(s) N/A   Date

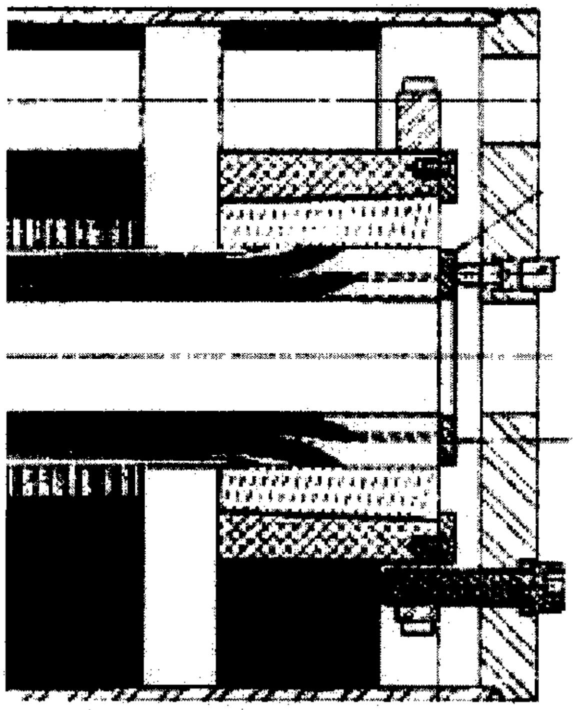
5.0 End Plate Installation

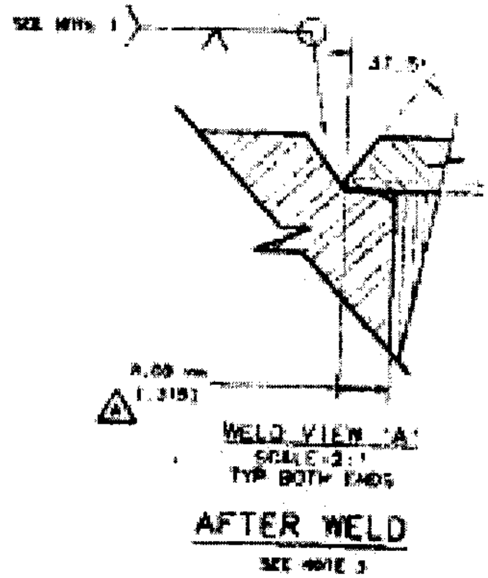
5.1 Clean the Non-lead End Plate area with Isopropyl Alcohol (Fermi stock 1920-0300) Kimwipes (Fermi stock 1660-2500) or equivalent, and a vacuum to remove all dirt and foreign materials.

N/A
Technician ____________________ Date ____________________

5.2 Install the Non-Lead End – End Plate (ME-369750) as per (ME-369655).

NON-LEAD END





Quadrant 1 is UP.

Note(s):

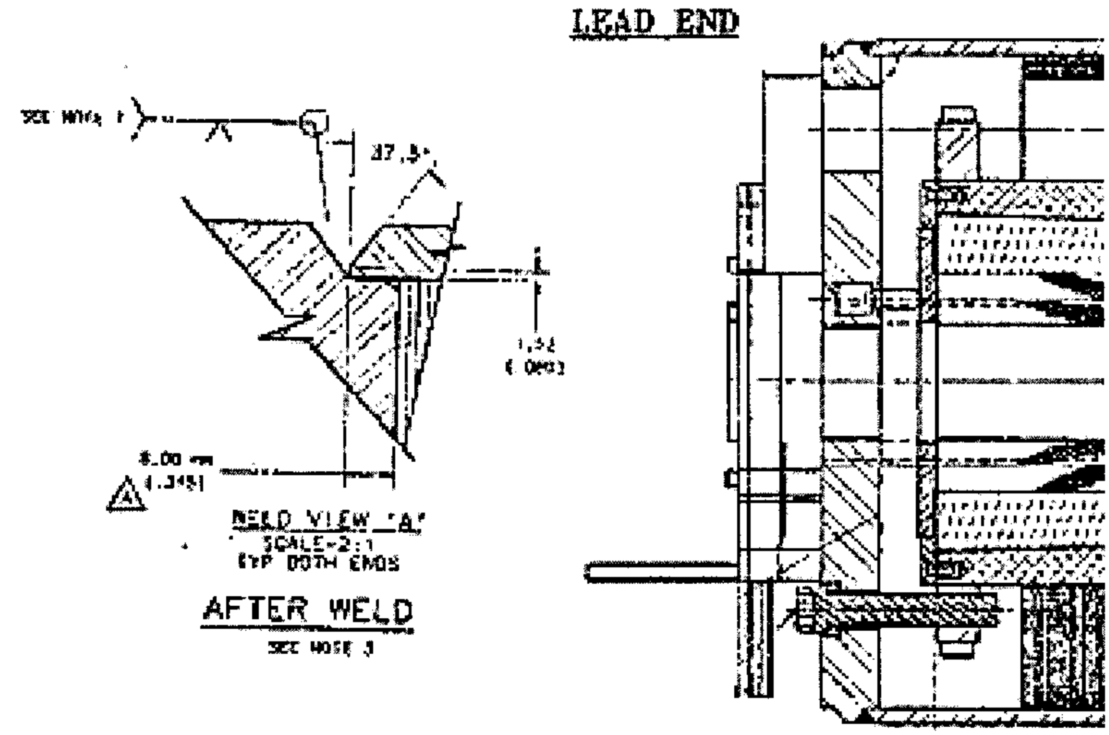
The End Plate should be facing outward so the stamped or marked area with the nomenclature, part number, and "Top" is visible.
Check the Tapped holes prior to installation for damage.

N/A
Technician ____________________ Date ____________________

5.3 Clean the Lead End Plate Area with Isopropyl Alcohol (Fermi stock 1920-0300), Kimwipes (Fermi stock 1660-2500) or equivalent and vacuum to remove all dirt and foreign materials.

Technician(s) ________ Date 1-4-02

5.4 Install the Lead End – End Plate (ME-369749) as per (ME-369655). While installing, pull out the Instrumentation and Power Lead Wires through the proper openings as per the figure below.



Quadrant 1 is UP.

Note(s):

The End Plate should be facing outward so the stamped or marked area with the nomenclature, part number, and "top" is visible.
Check the Tapped holes prior to installation for damage.

Technician(s) ________ Date 1-4-02

5.5 Record the Length from the Outer Edge of the Lead End Plate to the Outer Edge of the Non-lead End Plate before welding.

All Quadrant lengths must be with in .030" of each other.

Position of the Measurement	Measurement in Inches (For Reference Only)
Q1	225 11/16
Q2	225 5/8
Q3	225 11/16
Q4	225 11/16

Technician(s) Date 1-4-02

X 5.6 Verify that the End Plates are properly installed as per the Final Coldmass Assembly (ME-369655).

Production Engineer/Designee Date 1-4-02

5.7 While the Non-Lead End Plate is in position as per the Final Cold Mass Assembly (ME-369655), weld the Non-Lead End – End Plate to the Cold Mass Skin as per (ME-369655).

N/A
Weldor Date

5.8 Clean the Weld area with a Stainless Steel Wire Brush (Fermi stock 1246-0860), Isopropyl Alcohol (Fermi stock 1920-0300), Kimwipes (Fermi stock 1660-2500) or equivalent and vacuum.

N/A
Technician(s) Date

5.9 While the Lead End Plate is in position as per the Final Cold Mass Assembly (ME-369655). Weld the Lead End –End Plate to the Cold Mass Skin as per (ME-369655).

Michael J. Cooper
Weldor Date 1-7-02

5.10 Clean the Weld with a Stainless Steel Wire Brush (Fermi stock 1246-0860), Vacuum, Isopropyl Alcohol (Fermi stock 1920-0300) and Kimwipes (Fermi stock 1660-2500) or equivalent.

Technician(s) Dmuzyk Date 1-7-02

5.11 Record the Length from the Outer Edge of the Lead End Plate to the Outer Edge of the Non-lead End Plate after welding.

Note(s):

The measurement should be within 1/8" of the readings taken in step 5.5.

Position of the Measurement	Measurement in Inches	Nominal
Q1	225 5/8	225.926"
Q2	255 9/16	225.926"
Q3	225 ~~[illegible]~~ 1/2 DM	225.926"
Q4	225 9/16	225.926"

Technician(s) Dmuzyk Date 1-7-02

6.0 Bolt and Bullet Installation

6.1 Apply Areolex (open Purchase - Chemical Research Co.) to all threaded parts being installed onto the End Plates except the bolts. Apply anti-seize to the Axial Preload Bolts (MB-369267)

Technician _______ Date 1-7-02

6.2 Assemble the Bullet Assemblies (MD-369293) for the Lead and Non-Lead End.

Technician _______ Date 1-7-02

6.3 Install the Bullet Pusher Screws (MB-344583) and the Bullet Load Slugs (MB-344584) in (4) places on the Lead End and (4) places on the NON-Lead End as per (ES-369871). Be careful not to damage the wires or the solder connections.

Note(s):

Before the final torque is applied the Production Engineer and/or Magnet Physicist are to be present.

Technician _______ Date 1-7-02

X 6.4 Verify the stabilization of the Torque applied to the Bullet Pusher Screws.
If no anomalies occurred during this process, state "no anomalies", else comment below.

Comment:

NO ANOMALIES

Responsible Authority/Physicist _______ Date 1-8-02

7.0 Electrical Inspection

7.1 Perform an electrical inspection on each of the individual Inner Coils, Outer Coils, Quadrants and the Magnet. Refer to the Valhalla and Leader Free Standing Coil Measurement Procedure (ES-292306), and the Procedure for Electrical Inspection of Voltage Taps (ES-301383).

Note(s):

Ensure that all measurements are recorded correctly, and have the proper value and symbol (i.e., mΩ, mH, etc.).

Valhalla 4300B settings:

Test current ____________ Off (not testing)
Power ____________ On
Full scale voltage ____________ 20 mV
Amp selector knob ____________ 1 A
Temperature compensator ____________ On
Test current ____________ On (testing)

Hp 4284:

Function ____________ "Ls-Q" selected

Record the Serial Number of the test equipment used.

Valhalla 32-858

HP 4284 2848J00912

Resistance		Inner	Outer	Total	Pass	Fail
Nominal		345 mΩ to 390 mΩ	410 mΩ to 455 mΩ	560 to 585 mΩ		
Quadrant 1	Inner	.2543 mΩ				
	Outer		.3170 mΩ			
	Total			.5714 mΩ		
Quadrant 2	Inner	.2537 mΩ				
	Outer		.3176 mΩ			
	Total			.5713 mΩ		
Quadrant 3	Inner	.2582 mΩ				
	Outer		.3182 mΩ			
	Total			.5747 mΩ		
Quadrant 4	Inner	.2573 mΩ				
	Outer		.3179 mΩ			
	Total			.5757 mΩ		

Inductance		Inner	Outer	Total	Pass	Fail
Nominal		620-650 µH	1.120 to 1.17 mH	2.880 to 2.935 mH		
Quadrant 1	Inner	520.905 µH				
	Outer		854.646 mH			
	Total			2.29236 mH		
Quadrant 2	Inner	519.182 µH				
	Outer		850.840 mH			
	Total			2.28610 mH		
Quadrant 3	Inner	520.801 µH				
	Outer		849.526 mH			
	Total			2.28740 mH		
Quadrant 4	Inner	522.074 µH				
	Outer		853.301 mH			
	Total			2.29470 mH		

Q-Factor		Inner	Outer	Total	Pass	Fail
Nominal		3.0 to 3.5	4.3 to 5.0	4.5 to 5.2		
Quadrant 1	Inner	2.94				
	Outer		2.79			
	Total			4.68		
Quadrant 2	Inner	2.94				
	Outer		2.78			
	Total			4.69		
Quadrant 3	Inner	2.93				
	Outer		2.77			
	Total			4.64		
Quadrant 4	Inner	2.91				
	Outer		2.76			
	Total			4.62		

D Jurczyk
Inspector

1-8-02
Date

	Nominal	Measurements
Resistance	2.3 Ω	2.536 Ω
Q@ 1 kHz	4.3	4.92
Inductance (Ls) @ 1 kHz	17 mH	13.4992 mH

D Murcyjf
Inspector

1-8-02
Date

Resistance Test	Limit	Actual Measurement	Pass	Fail
Heater Strips 1/2	9.10 to 9.50 Ω	19.837 B- Ω		
Heater Strips 2/3	9.10 to 9.50 Ω	19.847 A- Ω		
Heater Strips 3/4	9.10 to 9.50 Ω	19.837 B+ Ω		
Heater Strips 4/1	9.10 to 9.50 Ω	19.847 A+ Ω		

D Murcyjf
Inspector

1-8-02
Date

7.2 Verify torque on Pre-Load Bolts as per (ES-369871).

D Murcyjf
Technician(s)

1-8-02
Date

8.0 Make Quadrant Splices

DR # HGQ-0298

8.1 Attach the Coil Splice Block #1 (MD-344908), the Coil Splice Block #2 (MD-344909), the Coil Splice Block #3(MD-344910) and the Coil Splice Block #4 (MD-344911) to the Lead End Plate (ME-369572) as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) ______________________ Date 1-9-02

8.2 Attach all three Support Block - Bases (MB344942) and the Coil Support Block (MA-369215) to the Lead End Plate (ME-369572) as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) ______________________ Date 1-9-02

8.3 Form Power Leads into slots in Coil Splice Blocks as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) ______________________ Date 1-9-02

8.4 Attach the Coil Splice - Intermediate Block #1 (MD-344919), both the Coil Splice - Intermediate Block #2, #3 (MD-344920) and the Coil Splice - Intermediate Block #4A (MD-344921) to the Coil Splice Blocks as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) ______________________ Date 1-9-02

8.5 Form Power Leads into slots in Coil Splice - Intermediate Blocks as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) ______________________ Date 1-9-02

8.6 Attach the Coil Splice - Intermediate Block #4B (MD-369844) to the Coil Splice - Intermediate Block #4A as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) ______________________ Date 1-9-02

8.7 Form Power Leads into slots in Coil Splice - Intermediate Blocks as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) ______ Date 1-10-02

8.8 Attach all four Support Block Covers to the Coil Splice - Intermediate Blocks as per the Final Coldmass Assembly (ME-369655) and the Quadrant Splice Assembly (MD-344925).

Technician(s) ______ Date 1-10-02

8.9 Attach all three Support Block - Tops (MB-344795) to the Support Block - Base (MB-344942) and all three Fillers (MB-369214) as per Quadrant Splice Assembly (MD-344925).

Technician(s) ______ Date 1-10-02

8.10 Attach (2) Voltage Taps to each Quadrant Splice and (2) Voltage Taps to each Power Lead.

Locations	Wire Type (MA-369832)	Completed
Power Leads Q4I	26 Gauge	✓
	26 Gauge	✓
Power Leads Q3I	26 Gauge	✓
	26 Gauge	✓
QS A Q2O / Q1O (1/2 Coil Tap)	26 Gauge	✓
	26 Gauge	✓
QS B Q3O / Q1I (1/4 Coil Tap)	26 Gauge	✓
QS C Q4O / Q2I (1/4 Coil Tap)	26 Gauge	✓

Technician(s) ______ Date 1-14-02

8.11 Install Springboard Assembly (MC-369842 & MC-369843) onto the Cold Mass Assembly. Wrap the Springboard Assemblies in Kapton.

Technician(s) ______ Date 1-14-02

9.0 Lead End Electrical Installations

9.1 Perform an electrical inspection on each of the individual Inner Coils, Outer Coils, Quadrants and the Magnet. Refer to the Valhalla and Leader Free Standing Coil Measurement Procedure (ES-292306), and the Procedure for Electrical Inspection of Voltage Taps (ES-301383).

Note(s):

Ensure that all measurements are recorded correctly, and have the proper value and symbol (i.e., mΩ, mH, etc.).

Valhalla 4300B settings:

Test current	______________	Off (not testing)
Power	______________	On
Full scale voltage	______________	20 mV
Amp selector knob	______	1 A
Temperature compensator	______	On
Test current	______________	On (testing)

Hp 4284:

Function	______________	"Ls-Q" selected

Record the Serial Number of the test equipment used.

Valhalla 32858

HP 4284 2948J00912

Resistance		Inner	Outer	Total	Pass	Fail
Nominal		345 mΩ to 390 mΩ	410 mΩ to 455 mΩ	560 to 585 mΩ		
Quadrant 1	Inner	255.7 mΩ				
	Outer		318.2 mΩ			
	Total			571.7 mΩ		
Quadrant 2	Inner	254.6 mΩ				
	Outer		318.4 mΩ			
	Total			572.2 mΩ		
Quadrant 3	Inner	256.3 mΩ				
	Outer		318.9 mΩ			
	Total			573.6 mΩ		
Quadrant 4	Inner	254.9 mΩ				
	Outer		318.2 mΩ			
	Total			572.8 mΩ		

TRR

Inductance		Inner	Outer	Total	Pass	Fail
Nominal		620-650 μH	1.120 to 1.17 ~~mH~~ μH	2.880 to 2.935 mH		
Quadrant 1	Inner	SNG 546.711 ~~696.80~~ μH				
	Outer		SNG 883.328 ~~[illegible]~~ μH			
	Total			2.3361 ~~2.9186~~ SNG mH		
Quadrant 2	Inner	544.993 μH				
	Outer		879.619 μH			
	Total			2.3291 mH		
Quadrant 3	Inner	542.812 μH				
	Outer		875.682 μH			
	Total			2.3161 mH		
Quadrant 4	Inner	544.786 μH				
	Outer		878.629 μH			
	Total			2.3233 mH		

Q-Factor		Inner	Outer	Total	Pass	Fail
Nominal		3.0 to 3.5	4.3 to 5.0	4.5 to 5.2		
Quadrant 1	Inner	1.06				
	Outer		1.36			
	Total			1.99		
Quadrant 2	Inner	1.05				
	Outer		1.36			
	Total			1.99		
Quadrant 3	Inner	1.05				
	Outer		1.36			
	Total			1.98		
Quadrant 4	Inner	1.05				
	Outer		1.35			
	Total			1.97		

Inspector   Date 1/17/02

	Nominal	Measurements
Resistance	2.3 Ω	2.292 Ω
Q@ 1 kHz	4.3	5.01
Inductance (Ls) @ 1 kHz	17 mH	13.4704 mH

Inspector   Date 1/17/02

B+ : B-

Resistance Test	Limit	Actual Measurement	Pass	Fail
Heater Strips 1/2	9.10 to 9.50 Ω	—— Ω		
Heater Strips 2/3	9.10 to 9.50 Ω	19.864 Ω		
Heater Strips 3/4	9.10 to 9.50 Ω	—— Ω		
Heater Strips 4/1	9.10 to 9.50 Ω	19.862 Ω		

A+ : A-

Inspector   Date 1/17/02

Traveler Title:	Specification No:	Revision:	DR No:
LHC Final Cold Mass Assembly Traveler	5520-TR-333498	A	HGQ-0270

Step No:	Drawing No:	Routing Form No:	Serial No:
3.1	5520-ME-369655		MQXB01

Discrepancy Description:

The non-lead end outer saddles are cracked in the center of each saddle and they are bulging out from the face of the magnet.

Originator: Steve Gould

Date: 11/9/01

Cause of Nonconformance:

The last 2 cm of parting plane saddle shim have been removed, allowing the saddles to fill the gaps by bending, causing the cracks.

Responsible Authority: Rodger Bossert

Date: 11/9/01

Disposition:

Shim the uneven areas longitudinally and continue.

Responsible Authority: Rodger Bossert

Date: 11/9/01

Corrective Action to Prevent Recurrence:

Consider lengthening Non-Lead End Outer Saddles by approximately 1/2 cm. This will provide more strength in the saddle section as well as lengthening the outer coils to be the same as the inner coils after springback.

Responsible Authority: Rodger Bossert

Date: 11/9/01

Corrective Action/Disposition Verified By: Rodger Bossert

Date: 11/9/01

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Will Configuration be affected?: ☒ YES ☒ NO

c

Identified problem area:

☑ Material ☐ Manpower ☐ Method ☐ Machine ☐ Measurement

Reviewed By: Bob Jensen

Date: 5/22/02

Traveler Title: LHC Final Cold Mass Assembly Traveler

Specification No: 5520-TR-333498

Revision: A

DR No: HGQ-0284

Step No: 8.2

Drawing No: 5520-ME-369655

Routing Form No:

Serial No: MQXB01

Discrepancy Description:

One of the support block bases has been changed. Need the new base.

Originator: Steve Gould

Date: 12/7/2001

Cause of Nonconformance:

The part change has not yet been incorporated into the parts kit list.

Responsible Authority: Rodger Bossert

Date: 12/7/2001

Disposition:

Get proper block (MB-369875) and use in Assembly.

Responsible Authority: Rodger Bossert

Date: 12/7/2001

Corrective Action to Prevent Recurrence:

Add new block to parts kit list and traveler. Replace previous part (3449420) with (369875). (TRR No. 1318)

Responsible Authority: Rodger Bossert

Date: 12/7/2001

Corrective Action/Disposition Verified By: Rodger Bossert

Date: 12/7/2001

Will Configuration be affected?: ☐ YES ☑ NO

Identified problem area:

☐ Material ☐ Manpower ☑ Method ☐ Machine ☐ Measurement

Reviewed By: Bob Jensen

Date: 3/20/2002

Traveler Title: LHC Final Cold Mass Assembly Traveler

Specification No: 5520-TR-333498

Revision: A

DR No: HGQ-0286

Step No: 8.9

Drawing No: 5520-ME-369655

Routing Form No:

Serial No: MQXB01

Discrepancy Description:

Fastener for the support block top does not fit for base #369875.

Originator: Steve Gould

Date: 12/7/2001

Cause of Nonconformance:

Screw is too long. (Entered into Database on 7/11/02 - John Szostak)

Responsible Authority: Rodger Bossert

Date: 12/7/2002

Disposition:

Obtain screws of proper length. (Entered into Database on 7/11/02 - John Szostak)

Responsible Authority: Rodger Bossert

Date: 12/7/2001

Corrective Action to Prevent Recurrence:

Modify drawing to shorten screws. (Entered into Database on 7/11/02 - John Szostak)

Responsible Authority: Rodger Bossert

Date: 12/7/2001

Corrective Action/Disposition Verified By: Rodger Bossert

Date: 12/7/2001

Will Configuration be affected?: ☐ YES ☑ NO

Identified problem area:

☑ Material ☐ Manpower ☐ Method ☐ Machine ☐ Measurement

Reviewed By: Bob Jensen

Date: 2/13/2002

Traveler Title: LHC Final Cold Mass Assembly Traveler

Specification No: 5520-TR-333498

Revision: A

DR No: HGQ-0290

Step No: 9.2

Drawing No: ME-369655

Routing Form No:

Serial No: MQXB01

Discrepancy Description:

Magnet was found to have a circuit A heater to ground failure at 3 kV.

Originator: Jim Rife

Date: 12/11/2001

Cause of Nonconformance:

Heater wire was shorted to End pre-load plate. This happened because the heater wires were routed in a non-conventional manner. (Entered into Database on 7/11/02 - John Szostak)

Responsible Authority: Rodger Bossert

Date: 1/8/2002

Disposition:

Remove End Plate, re-route heater wires in the conventional manner (adjacent to the leads), and continue. (Re-issue 333498, Steps 4.0 to 9.1 omitting steps not applicable.) (Entered into Database on 7/11/02 - John Szostak)

Responsible Authority: Rodger Bossert

Date: 1/8/2002

Corrective Action to Prevent Recurrence:

Heater wires will, in the future, be routed in the conventional manner. (Entered into Database on 7/11/02 - John Szostak)

Responsible Authority: Rodger Bossert

Date: 1/8/2002

Corrective Action/Disposition Verified By: Rodger Bossert

Date: 1/8/2002

Will Configuration be affected?: ☐ YES ☑ NO

Identified problem area:

☐ Material ☐ Manpower ☐ Method ☐ Machine ☑ Measurement

Reviewed By: Bob Jensen

Date: 1/8/2002

Traveler Title:	Specification No:	Revision:	DR No:
LHC Final Cold Mass Assembly Traveler	5520-TR-333498	A	HGQ-0298

Step No:	Drawing No:	Routing Form No:	Serial No:
8.1	5520-ME-369655		MQXB01

Discrepancy Description:

Due to replacing endplate the bullets stick out of endplate. Splice Support blocks now rest opon bullets, not flat end plate surface. (Entered into Database on 7/11/02 - John Szostak)

Originator: Donald Nurczyk

Date: 1/8/2002

Cause of Nonconformance:

End plate was replaced, making Lead End slightly shorter for this magnet only. Bullets therefore stick out beyond End plate surface. (Entered into Database on 7/11/02 - John Szostak)

Responsible Authority: Rodger Bossert

Date: 1/8/2002

Disposition:

Grind out areas of interference on splice blocks, then proceed with assembly. (Entered into Database on 7/11/02 - John Szostak)

Responsible Authority: Rodger Bossert

Date: 1/8/2002

Corrective Action to Prevent Recurrence:

This problem will not exist when hipotting failure problem is solved. Refer to DR No. HGQ-0290. (Entered into Database on 7/11/02 - John Szostak)

Responsible Authority: Rodger Bossert

Date: 1/8/2002

Corrective Action/Disposition Verified By: Rodger Bossert

Date: 1/8/2002

Will Configuration be affected?: ☐ YES ☑ NO

Identified problem area:

☐ Material ☐ Manpower ☑ Method ☐ Machine ☐ Measurement

Reviewed By: Bob Jensen

Date: 1/8/2002